AN ESTIMATE OF JUVENILE FISH DENSITIES IN SKILAK AND KENAI LAKES, ALASKA, THROUGH THE USE OF DUAL-BEAM HYDROACOUSTIC TECHNIQUES IN 1993-1994

By

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ABSTRACT

The number and distribution of sockeye salmon *Onchorhynchus nerka* rearing in two glacial lakes of the Kenai River drainage was estimated in 1993 and 1994 from hydroacoustic surveys. Using dual-beam acoustic techniques, mean *in situ* target strength ranged from -54.1 dB to -58.4 dB. Densities of fish estimated in May 1993 suggested a significant over-winter mortality of age-0 sockeye salmon. Surviving fish were concentrated at 20-40 m in May and showed indications of moving toward the surface with increasing darkness. In October 1993 the number of age-0 sockeye salmon in Kenai and Skilak Lakes was estimated at 35,687,400. In November 1993, the number of age-0 sockeye salmon in Skilak Lake was estimated at 27,608,400. By April 1994 a minimum of 15,375,800 age-0 sockeye salmon had survived the winter in Skilak Lake. In September/October 1994 a total of 12,441,900 sockeye were estimated in Kenai/Skilak Lakes. Age-0 sockeye salmon numbered 11,159,500 and age-1 were estimated at 1,282,500 fish. Age-0 sockeye salmon mean length and weight were measured for all sample periods. A linear relationship between potential egg deposition and fall fry numbers remained during this period though the residual for the 1992 brood year was one of the largest.

KEY WORDS: hydroacoustic survey, sockeye salmon, target strength, glacial lake, Alaska, *Onchorhynchus nerka*

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) began investigations in 1972 to assess juvenile sockeye salmon *Onchorhynchus nerka* populations rearing in the major lakes of the Kenai River drainage (Figure 1; Davis et al. 1973). As part of these investigations, juvenile sockeye salmon were collected from Skilak and Kenai Lakes using tow nets to estimate relative abundance, age structure, and growth (Davis et al. 1974; Namtvedt and Friese 1976). However, the inefficiency of tow netting restricted the usefulness of these data for abundance estimates (Waltemyer 1981). Therefore, in 1986 ADF&G began developing new methods to enumerate fry using hydroacoustic equipment (Tarbox and King 1988a, 1988b).

Annual fall hydroacoustic surveys have been conducted in Kenai and Skilak Lakes since 1986 to develop a time series of juvenile sockeye salmon population estimates. Program objectives for the 1993-94 field investigation were to (1) estimate the number and spatial distribution of sockeye salmon juveniles, (2) determine the target strength distributions using dual-beam hydroacoustic techniques, (3) document the condition of juvenile sockeye salmon using length and weight measurements, and (4) estimate the age composition of sockeye salmon in each lake.

Since the initiation of the project in 1986 the standard procedure for estimating juvenile sockeye salmon abundance in Kenai and Skilak Lakes has been to conduct night-time hydroacoustic surveys during September or October. While this procedure was followed in 1993-94, we also conducted hydroacoustic work in Skilak Lake during May and November 1993 and April 1994. The objective of these supplemental studies was to define the depth distribution of rearing sockeye salmon in spring and fall and to assess survival of rearing sockeye salmon during the fall to winter transition period. In addition, we conducted an extensive tow netting program in 1993-94 to assess potential bias in the age composition allocation. This information is reported in a separate document.

METHODS

The equipment used for data acquisition consisted of a Biosonics Inc. Model 105[1] echo sounder with dual-beam receivers, a 420 kHz 6°/15° dual beam transducer mounted in a V-fin for towing, a Model 171 tape recorder interface, a Sony[1] digital audio tape (DAT) player, a chart recorder, and an oscilloscope. The selected pulse width was 0.4 ms and the pulse repetition rate was 5 pulses/s. Additional acoustic parameters used during data collection and processing are presented in Appendix A.1. Biosonics, Inc. calibrated the system before and following the surveys. The entire system was powered by 12-V batteries and carried in a 7.2-m vessel powered by outboard motors. Vessel speed along each transect was estimated at 2.0 to 2.5 m/s. The transducer was

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towed approximately 1 m below the water surface during surveys. Equipment procedures were outlined in King and Tarbox (1988).

Dual-beam data recorded on DAT were processed through a Biosonics, Inc. Model 281 Echo Signal Processor[1] (ESP). A returning pulse was accepted as a valid target if the amplitude was below the bottom threshold of 7000 mV and above the counting threshold of 200 mV. Single targets were separated from multiple targets if the pulse width was within 20% of the transmitted pulse width at -6 dB and -18 dB. The maximum half-angle selected for data processing was 4°. Data were stratified in 5-m increments for analysis starting 2 m below the transducer, or 3 m below the water surface. Only data collected at range less than 97 m were accepted for processing. Examination of oscilloscope traces and echograms indicated that few fish were present below this depth.

Data generated by the dual beam processor were transferred to computer data files for analysis using the Biosonics, Inc. software "Target Strength Post Processing Program ESPTS." Computations of mean target strength and backscattering cross section were made from individual echoes, and a hard copy of the results was printed for each 5-m depth interval.

Estimates of fish density were made for each transect by echo integration using a Biosonics, Inc. ESP Model 221[1] echo integrator. Correction from the 40 log(R) setting used during data collection to the 20 log(R) used for data processing was accomplished by adjusting the B constant value for each depth stratum.

The echo integrator compiled data in 1-min sequences along each transect and sent outputs to computer files for further reduction and analysis using the Biosonics, Inc. software "Echo Integration Post Processing Program ESPCRNCH." Raw integrator outputs were edited to remove data that resulted from false bottom echoes. Where this occurred, fish densities were usually estimated using the average densities of adjacent sequences at the same depth. Overall fish density was obtained by calculating the average edited integrator output value across the transect for each depth stratum. These averages were multiplied by the integrator scaling factor derived from the mean backscattering cross-section value obtained from the ESPTS program. Mean backscattering cross section values were calculated for each depth stratum using data from those transects where false bottom did not occur or did not influence the target strength data.

The total number of fish (N_{ij}) for area stratum i based on transect j was estimated across depth stratum k. It consisted of the number of fish estimated by hydroacoustic gear in the midwater section (M_{ij}) plus an estimate of fish unavailable to the hydroacoustic gear because of their location near the surface (S_{ij}) or bottom (B_{ij}), or

$$N_{ij} = S_{ij} + M_{ij} + B_{ij} .$$

The midwater component was estimated as

$$M_{ij} = \sum_{k=1}^{K} a_i w_{ijk} m_{ijk} ,$$

where a_i represented the surface area (m^2) of area stratum i which was estimated using a planimeter and USGS maps of Skilak and Kenai Lakes, and w_{ijk} was the average depth (5m) of depth stratum k measured along transect j in area i. This depth would be less than the maximum 5 m if the bottom was detected within depth stratum k anytime along the transect. The mean fish density in area i depth k across transect j was m_{ijk} in number per m^3.

The estimated number of fish near the surface (0-3 m) in area i was

$$S_{ij} = a_{is} m_{ij1} ,$$

where a_{is} was the estimated volume (m^3) of the surface area stratum (0-3 m), and m_{ij1} was the mean fish density for the first ensonified depth strata (2-7 m below transducer) of transect j.

The estimated number of fish near the bottom was

$$B_{ij} = \sum_{k=1}^{K} b_{ijk} m_{ijk} ,$$

where b_{ijk} was the estimated volume (m^3) in area i of depth k that could not be ensonified due to the proximity of the bottom along transect j, and m_{ijk} was the estimated fish density (number per m^3) along transect j in area i depth k that was ensonified. In cases where all of depth stratum k was along the bottom, the mean density m_{ijk-1} from the next shallower depth strata (k-1) was used.

The abundance in area i (N_i) became the mean abundance estimated by each transect j, or

$$N_i = J^{-1} \sum_{j=1}^{J} N_{ij} ,$$

and its variance was estimated as

$$V(N_i) = \sum_{j=1}^{J} (N_{ij}-N_i)^2(J-1)^{-1}J^{-1} \quad .$$

Total abundance for each lake became the sum of its area estimates. Its variance became the sum of the area variances.

Age-specific estimates of the numbers of juvenile sockeye salmon (N_{ayi}) were estimated

$$N_{ayi} = N_{yi}\, p_{ayi},$$

where p_{ayi} was the proportion of fish caught in area i (n_{yi}) and year y of age a (n_{ayi}). Samples were pooled across areas not found to have significantly different age compositions (chi-square test). The pooled proportion for age a was then substituted for p_{ayi} for the appropriate areas.

The variance for N_{ayi} was estimated as the product of two random variables, p_{ayi} and N_{yi}, as

$$V(N_{ayi}) = N_{yi}^2 V(p_{ayi}) + p_{ayi}^2 V(N_{yi}) - V(p_{ayi})\, V(N_{yi}).$$

The total estimate for the Kenai and Skilak Lakes system became

$$N_{ay} = \sum_{all\ i} N_{ayi},$$

and its variance was estimated as

$$V(N_{ay}) = \sum_{all\ i} V(N_{ayi}) \quad .$$

We conducted a hydroacoustic survey during the day on 5 May 1993 to define fish abundance and depth distribution, in Skilak Lake (Figure 2). A second survey was conducted on 8-9 May to define diel vertical behavior of juvenile sockeye salmon. A single transect in Area 1 of Skilak Lake was replicated sixteen times in a 7-h period (1842 to 0203 hours; Figure 3). Because of low densities of fish in the study area, mean target strength data by depth were calculated by pooling results from the two surveys.

We used a stratified random sampling design for 1993 fall night surveys to distribute sampling effort and provide an acceptable way of calculating sampling error. We divided each lake into areas or sub-basins and randomly established survey transects within each of these areas. The number of transects was chosen to reduce the relative error to 0.25 for Skilak Lake and 0.3 for Kenai Lake. Our sample size was based on the average coefficient of variation observed from 1986 to 1989. Because of the configuration of Skilak Lake, a total of 13 transects perpendicular to shore were surveyed within three sub-basins (Figure 4). In Kenai Lake a total of 27 transects were surveyed within five sub-basins (Figure 5). The Kenai Lake survey was conducted on 4 October 1993 and the Skilak Lake survey on 26 September 1993.

Following the regular night hydroacoustic survey of Skilak Lake on 26 September, we returned to Skilak Lake on the nights of 16 and 18 November 1993 to ascertain fish abundance in the late fall/early winter. A total of thirteen transects was completed (Figure 6).

To evaluate overwinter survival we conducted a day survey of Skilak Lake on 25 April 1994. However, during that survey we suspected that we may have missed fish because of nearsurface orientation. Therefore we returned to Skilak Lake on 29 April 1994 to conduct a night survey (the same transects used in November 1993 were resurveyed in April).

We returned in September/October 1994 to survey both Kenai and Skilak Lakes as part of our normal operational plan (Figures 7 and 8). The survey design proceedure was the same as for the 1993 fall survey. However, rough water kept us from completing Area 5 in Kenai Lake. We, therefore, expanded Area 4 surface area to include Area 5 in the density estimate.

To estimate species composition of the targets mid water trawling was conducted in both lakes. The sampling program was designed to collect a minimum of 300 fish from each area of each lake. All captured fish were enumerated, identified, and preserved in 10% formalin. In the laboratory juvenile sockeye salmon were measured to the nearest millimeter (fork length), weighed to the nearest 0.1 g, and an age determined from scale samples using criteria outlined by Mosher (1969). Differences in age and species composition between areas were tested with chi-square analysis. Detailed methods and results of this effort are reported in a separate document (Carlson et. al, in press).

RESULTS

May 1993 Hydroacoustic and Tow Net Surveys

Sixteen thousand five hundred and ninety three echoes were used to estimate target strength distributions in Skilak Lake on 5 May 1993. Mean target strength was -55.04 dB with a standard deviation of 4.76 dB (Appendix A.2). The estimated fish population was only 859,240 (Table 1). No apparent concentration of fish was observed as fish distribution was similar to the relative volume estimates for each area (Table 2). No species apportionment was made since tow netting resulted in insufficient catches. The depth distribution of targets indicated no obvious surface orientation as peak densities were typically in the 20-40 m range (Figures 9 and 10).

On 8 May 1993 population estimates for Area 1, Skilak Lake, ranged from 476,020 to 4,646,700 fish depending on when the transect was conducted. Early evening estimates (1842 to 2004 hrs) typically were the lowest with peak estimates made between 2200 and 2334 hrs (Table 3). Density estimates by depth indicated that fish were distributed at deeper depths during the early evening with higher densities recorded near surface as night advanced (Figures 11 and 12). Target strength measurements were essentially the same as the 5 May 1993 survey (mean value -54.09 dB, Appendix A.3).

September/October 1993 Night Hydroacoustic and Day Tow Net Surveys

A total of 44,813 echoes in Kenai Lake and 138,697 in Skilak Lake were used to estimate target strength distributions. As in past fall surveys, calculated mean target strengths decreased with depth (Figure 13). Mean target strength for Kenai Lake was -57.6 dB (Appendix A.4). Near-surface measurements were -55.52 dB in contrast to -59.19 dB at a depth of 52-57 m. In Skilak Lake the mean target strength was -56.68 dB. Mean target strength decreased from a near surface value of -54.47 dB to -57.21 dB at 37 m (Appendix A.5).

The total estimated number of fish in both lakes was 38,108,400 (Table 4). Approximately 11%, or 4,355,300 fish, were found in Kenai Lake and the remaining 33,753,100 fish in Skilak Lake. An estimated 55.2% of the fish in Skilak Lake were located in Area 1, which comprised 28.9% of the lake volume . Within Kenai Lake 31.5% of the fish were located in Area 4, which composed 29.3% of the lake volume (Table 5).

The maximum fish density observed in Skilak Lake was 0.089 fish/m^3 between 22-27 m along Transect 6 of Area 1. Maximum densities of fish were recorded in the 17-22 m depth range for 6 of the 13 transects. Two transects had maximum densities deeper in the water column and five shallower.

The maximum density of fish observed in Kenai Lake was 0.011 fish/m^3 between 17-22 m along Transect 1 of Area 2. Maximum densities of fish at 12 transects was between 22-27 m. Six transects had maximum densities at deeper strata and nine shallower.

Sockeye salmon were the predominant species in catches from both lakes, representing nearly 100% of the total catch for both lakes (Table 6). Age-1 sockeye salmon made up 0.1% and age-0 composed 99.9% of the Kenai Lake juvenile sockeye estimate (N = 2.973; Table 6). Within Skilak Lake, age-0 sockeye salmon comprised 94.8% of the estimate (N = 2,879; Table 6).

After adjusting the total number of targets using species and age composition data from tow net samples, the number of juvenile sockeye salmon in both lakes was estimated at 37,420,000. Of this total, 35,687,400 were age-0 sockeye salmon produced by the 1992 spawning population, and 1,732,700 were age-1 sockeye salmon produced by the 1991 spawning population (Table 6).

Mean length of age-0 sockeye salmon in Skilak Lake was 49 mm and mean weight was 1.2 g. Age-1 sockeye salmon in Skilak Lake had a mean length of 75 mm and weight of 4.5 g. Mean size and weight of age-0 sockeye salmon in Kenai Lake was 45 mm and 1.0 g. They were smaller (N.S.C.) in size than those collected in Skilak Lake (Table 7).

November 1993 Night Hydroacoustic and Day Tow Net Survey

As expected, Skilak Lake mean fish target strength measurements in November 1993 were within 0.14 dB of the September values (mean -56.54 dB). However, in contrast to the September survey no obvious trend of decreasing target strength measurements with depth were observed in the data set (Appendix A.6).

A total of 29,091,000 fish were estimated in Skilak Lake (Table 8). The majority of fish targets (48.6%) were observed in Area 3 which comprised only 23.1% of the lake volume (Table 9). Tow netting indicated that 98.1% of the fish were sockeye salmon. Age-0 sockeye salmon numbered 27,608,400 while age-1 sockeye salmon comprised 1.9% of the sockeye population (527,000 fish; Table 10).

Comparing the mean size of age-0 and age-1 sockeye salmon indicated that no increase in length or weight took place between September and November (N.S.C.). Age-0 sockeye salmon were 48 mm (S.D. = 5mm, N= 1856) and 1.0 g (S.D.= 0.3, N = 1856) in November. Age-1 sockeye salmon were 75 mm (S.D. = 5, N = 43) and 4.1 g (S.D. = 0.8, N = 43).

April 1994 Hydroacoustic and Tow Net Surveys

A daylight survey on 25 April 1994 estimated 7,339,800 fish present in Skilak Lake (Table 11). Fish were concentrated in Area 1, with 80.9% of the population occupying 38.1% of the lake

volume (Table 12). Mean target strength was approximately 2 dB lower (mean -58.41 dB) than the previous November estimate (Appendix A.7).

In contrast, the night survey of Area 1, Skilak Lake, on 29 April 1994 produced an estimate of 18,178,000 fish (Table 13), which was three times the daylight estimate. Mean target strength was -56.63 dB (Appendix A.8), which was within 0.09 dB of the November estimate and 1.78 dB of the April daylight estimate. Based on extensive tow netting, sockeye salmon comprised 98.1% of the fish population. Age-1 sockeye salmon contributed 86.2% (15,375,800 fish) of the total sockeye estimate (Table 14).

Mean size of sockeye salmon were as follows: 1) Age-0 were 28.7 mm (S.D. = 1.0 mm, N = 10) in length and weighted 0.215 g (S.D. = 0.4, N = 10); 2) Age-1 were 53.3 mm (S.D. = 5.7 mm, N = 574) and 1.7 g (S.D. = 0.5 g, N = 574); and 3) Age-2 were 76.9 mm (S.D. = 4.6 mm, N = 65) and 4.5 g (S.D. = 4.6 g, N = 65).

September/October 1994 Night Hydroacoustic and Day Tow Net Survey

Mean fish target strength estimates for Skilak and Kenai Lakes were -54.14 and -54.44 dB, respectively (Appendix A.9 and A.10). Decreasing fish target strengths with depth during the fall surveys was again observed in 1994. However, the magnitude of the decrease was less than previous years (Figure 13). Within Skilak Lake near surface fish target strength was measured at -53.12 dB and decreased to -54.83 dB at 37-42 m. However, below this depth fish target strength increased slightly for a majority of the remaining depth strata (Appendix A.9). In Kenai Lake, except for the 2-7 m depth strata, target strength decreased from -53.71 dB at 7-12 m to -56.76 dB at 57-62 m (Appendix A.10).

The total number of fish in both Skilak and Kenai Lake was 12,514,000 (Table 15). Skilak Lake contributed 76.4% to the total population estimate (9,567,400 fish) which was the lowest on record (Figure 14). Distribution of fish in Skilak Lake was fairly evenly spread with Area 1 having 43.3% of the fish and 33.8% of the lake volume. Area 3 had slightly lower numbers (Table 16).

Sockeye salmon were the predominant species (99.3%) captured in tow nets. Age-0 sockeye salmon were 87.8% of the Skilak Lake sockeye estimate (8,353,900 fish) while in Kenai Lake they contributed 95.7% (2,805,600 fish, Table 17).

Mean size of Skilak Lake sockeye salmon juveniles were similar to the 1993 measurements (Table 7). However, age-0 fish were 0.2 g heavier that the 1993 fish. In contrast, Kenai Lake fish were almost twice as heavy than the 1993 cohort (Table 7).

DISCUSSION

This is the eighth year of hydroacoustic work on Skilak Lake, and during that time several trends have become evident in the data set. Fish-target strength estimates by depth in 1993 and 1994 were within historical bounds (Figure 13), and the trend of decreasing target strength with depth continued. This phenomenon appears related to the use of 420 kHz in this glacial lake system. Tarbox et al. (1993) found no decrease in target strength with depth using a 120 kHz system in Skilak Lake.

Schmidt et al. (1993) noted a relationship between potential egg deposition (a function of the number of spawners) and fall fry numbers in Skilak and Kenai Lakes over the available time series (Figure 15). The 1992 brood year production was the second highest measured. Schmidt (ADF&G, Soldotna, personal communication) has indicated that zooplankton abundance and behavior was abnormal and optimum for the 1993 rearing year in Skilak Lake. In contrast, the 1993 brood year production was 8 million fish below the regression model prediction.

The distribution of fish between Skilak and Kenai Lakes has also been very consistent: Skilak Lake generally produces between 80% and 90% of the counts (Figure 14). The relative abundance of fish in Skilak Lake in 1994 was the lowest on record and probably reflects reduced survival in Skilak Lake as opposed to increased production in Kenai Lake.

Overwinter survival of juvenile sockeye salmon in Skilak Lake is difficult to estimate since a number of variables are still unknown about juvenile sockeye salmon behavior in the Kenai River drainage. However, if one assumes that no immigration of juvenile sockeye into Skilak Lake took place between September 1993 and April 29, 1994 then the overwinter survival of age-0 juvenile sockeye was 49%. Because only Area 1 was surveyed at night in April the estimate is a minimum. If we assume that the distribution of fish between Areas on April 29th was the same as the day survey on April 25th an adjusted population estimate would increase overwinter survival to 61%.

Age analysis of the tow net data indicated that age specific depth differences in juvenile salmon abundance can significantly influenced the estimates of the number of age-1 or age-2 sockeye salmon (Carlson, ADF&G, Soldotna, personal communication). For example, in September and November 1993 the estimate of age-1 sockeye salmon in Skilak Lake was estimated at 1,726,000 and 527,000 fish respectively. In contrast, the age-2 estimate in April, 1994 was 2,456,600 fish or almost 4.7 times the November estimate. In September 1993 we collected data on age structure of the fish populations at various depths in Skilak Lake to evaluate this potential bias. Previous Skilak Lake investigations were limited to surface tows. In November 1993 we had not completed the analysis of the September data and were limited by time, weather, and gear to surface tows. By April 1994 we had completed the analysis of catch data and designed a program to collect age composition data at all depths as our hypothesis of depth age composition differences was not rejected (Carlson, ADF&G, Soldotna, personal communication). Therefore,

the estimates for September 1993 and 1994 and April 1994 are probably more reflective of the true age composition of the juvenile salmon population than the November estimate.

LITERATURE CITED

Davis, A.S., T. Namtvedt, and B.M. Barrett. 1973. Cook Inlet sockeye forecast and optimum escapement studies. Alaska Department of Fish and Game, Annual Technical Report, Anadromous Fish Conservation Act, Project AFC-41-2, Juneau.

Davis, A.S., B.M. Barrett, and L.H. Barton. 1974. Cook Inlet sockeye forecast and optimum escapement studies. Alaska Department of Fish and Game, Annual Technical Report, Anadromous Fish Conservation Act, Project AFC-41-3. Juneau.

King, B.E., and K.E. Tarbox. 1988. Outline of instructions for field operation of Biosonics Inc. dual beam hydroacoustic equipment and analysis of collected data. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2S88-14, Anchorage.

Mosher, K.H. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. U.S. Department of the Interior, Circular 317, Washington, D.C.

Namtvedt, T.B., and N.V. Friese. 1976. Investigations of Cook Inlet sockeye salmon. Annual Technical Report, Anadromous Fish Conservation Act, Project AFC-53-1, Juneau.

Schmidt, D., and 12 coauthors. 1993. Status report sockeye salmon overescapement, fish/shellfish study 27. Alaska Department of Fish and Game, State/Federal Natural Resource Damage Assessment studies.

Tarbox, K.E., and B.E. King. 1988a. An estimate of juvenile sockeye salmon (*Oncorhynchus nerka*) densities in Skilak and Kenai Lakes, Alaska through the use of dual beam hydroacoustic techniques. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2S88-2, Anchorage.

Tarbox, K.E., and B.E. King. 1988b. An estimate of juvenile fish densities in Skilak and Kenai Lakes, Alaska through the use of dual beam hydroacoustic techniques in 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2S88-4, Anchorage.

Tarbox, K.E., B.E. King, and L.K. Brannian. 1993. An estimate of juvenile fish densities in Skilak and Kenai Lakes, Alaska, through the use of dual beam hydroacoustic techniques in 1991. Alaska Department of Fish and Game, Technical Fishery Report 93-01, Juneau.

LITERATURE CITED (continued)

Waltemyer, D.L. 1981. A summary of tow netting for juvenile sockeye salmon on three Kenai Peninsula Lakes, 1973 to 1979. Alaska Department of Fish and Game, Division of Commercial Fisheries, Cook Inlet Data Report 81-1, Soldotna.

Table 1. Estimated number of fish in Skilak Lake, Alaska, on 5 May 1993.

Lake	Area	Transect	Estimated Number of Fish: Surface	Midwater	Bottom	Total	Area Mean	Variance
Skilak	1	1	1.9570E+03	2.4694E+05	3.1609E+04	2.8051E+05		
		2	8.4735E+03	2.8523E+05	1.5436E+04	3.0914E+05		
		3	1.9454E+04	2.3779E+05	2.4274E+04	2.8152E+05	2.7675E+05	7.0858E+08
		4	3.0749E+03	3.0480E+05	2.6689E+04	3.3456E+05		
		5	1.2974E+03	1.2890E+05	4.7845E+04	1.7804E+05		
	2	1	0.0000E+00	1.7673E+05	1.3561E+04	1.9029E+05		
		2	6.5056E+03	3.6209E+05	2.2847E+04	3.9144E+05	3.5233E+05	7.1496E+09
		3	0.0000E+00	4.5222E+05	2.3037E+04	4.7526E+05		
	3	1	6.3281E+03	4.2285E+05	4.3468E+04	4.7265E+05		
		2	0.0000E+00	2.0449E+05	3.0577E+04	2.3507E+05	2.3015E+05	7.5193E+09
		3	0.0000E+00	1.1389E+05	1.2535E+04	1.2643E+05		
		4	0.0000E+00	8.0906E+04	5.5644E+03	8.6470E+04		
	TOTAL						8.5924E+05	1.5377E+10

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Table 2. Areas, volume and fish estimates (%) in Skilak Lake, Alaska, day survey, 5 May 1993.

	Skilak Lake		
Area	Surface Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)	Number of Fish (%)
1	43.03 (43.5%)	1734.0 (27.8%)	26.8
2	33.46 (33.8%)	2782.0 (44.6%)	41.0
3	22.50 (22.7%)	1725.0 (27.6%)	32.2
Total	98.99 (100.0%)	6241.0 (100.0%)	100.0

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Table 3. Estimated number of fish available to the hydroacoustic techniques in Skilak Lake, Alaska, 8 May 1993.

Date	Area	Transect	Beginning Time	Estimated Number of Fish
May 8, 1993	1	1	1842	476,020
		2	1908	972,920
		3	1935	684,610
		4	2004	581,980
		5	2033	1,220,300
		6	2119	1,075,500
		7	2143	1,145,600
		8	2207	4,646,700
		9	2232	2,548,200
		10	2311	2,679,400
		11	2334	1,579,800
May 9, 1993	1	12	0005	1,195,100
		13	0035	1,108,200
		14	0105	1,396,300
		15	0136	1,529,300
		16	0203	2,220,200

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Table 4. Estimated number of fish in Skilak and Kenai Lakes, Alaska in September and October 1993.

Lake	Area	Transect	Estimated Number of Fish: Surface	Midwater	Bottom	Area Total	Mean	Variance
Skilak	1	1	1.9286E+06	1.5736E+07	3.6244E+06	2.1289E+07		
		2	2.7109E+06	2.4576E+07	2.6964E+06	2.9983E+07		
		3	7.6266E+05	1.5910E+07	1.2624E+06	1.7935E+07	1.8637E+07	8.9830E+12
		4	1.7298E+06	1.7345E+07	1.8244E+06	2.0899E+07		
		5	2.6993E+06	4.8310E+06	1.4507E+06	8.9810E+06		
		6	2.1816E+06	6.4490E+06	4.1013E+06	1.2732E+07		
	2	1	6.4042E+04	5.9890E+06	6.2774E+03	6.0593E+06		
		2	1.6543E+05	7.2300E+06	1.4472E+05	7.5402E+06	7.4378E+06	3.9326E+11
		3	7.3227E+04	8.1650E+06	4.7577E+05	8.7140E+06		
	3	1	4.3268E+05	1.3678E+07	9.3483E+05	1.5046E+07		
		2	4.5779E+05	7.7010E+06	2.9387E+05	8.4527E+06	7.6783E+06	7.3499E+12
		3	1.4101E+05	3.0790E+06	8.6931E+04	3.3069E+06		
		4	8.6670E+04	3.7730E+06	4.8478E+04	3.9081E+06		
	TOTAL						3.3753E+07	1.6726E+13
Kenai	1	1	1.3593E+02	2.2680E+05	7.4360E+03	2.3437E+05		
		2	3.4694E+02	4.5853E+05	5.8538E+04	5.1741E+05		
		3	3.5805E+03	2.9075E+05	7.3466E+04	3.6780E+05	3.7444E+05	2.6827E+09
		4	0.0000E+00	2.4403E+05	2.5795E+04	2.6983E+05		
		5	0.0000E+00	2.9858E+05	2.1498E+04	3.2008E+05		
		6	6.2995E+02	4.6830E+05	6.8223E+04	5.3715E+05		
	2	1	7.3318E+02	1.9670E+06	0.0000E+00	1.9677E+06		
		2	0.0000E+00	9.6065E+05	0.0000E+00	9.6065E+05		
		3	9.1290E+03	7.0240E+05	0.0000E+00	7.1153E+05	1.1073E+06	8.4964E+10
		4	3.8910E+02	7.8897E+05	0.0000E+00	7.8936E+05		
	3	1	5.5683E+03	4.9268E+05	0.0000E+00	4.9825E+05		
		2	0.0000E+00	2.8979E+05	0.0000E+00	2.8979E+05		
		3	0.0000E+00	4.9482E+05	0.0000E+00	4.9482E+05	3.8204E+05	2.6829E+09
		4	0.0000E+00	2.4448E+05	0.0000E+00	2.4448E+05		
		5	3.8798E+03	3.7900E+05	0.0000E+00	3.8288E+05		
	4	1	1.1691E+05	9.7567E+05	0.0000E+00	1.0926E+06		
		2	5.8630E+04	1.9775E+06	0.0000E+00	2.0361E+06		
		3	3.9950E+04	1.5705E+06	0.0000E+00	1.6105E+06	1.3704E+06	4.9284E+10
		4	1.8882E+04	1.3618E+06	0.0000E+00	1.3807E+06		
		5	1.4425E+04	7.1756E+05	0.0000E+00	7.3199E+05		
	5	1	5.1579E+04	3.2285E+05	0.0000E+00	3.7443E+05		
		2	1.1440E+05	5.3571E+05	0.0000E+00	6.5011E+05	1.1212E+06	4.1647E+10
		3	2.5111E+05	1.4519E+06	0.0000E+00	1.7030E+06		
		4	1.0149E+05	1.0844E+06	0.0000E+00	1.1859E+06		
		5	7.1941E+04	7.1263E+05	0.0000E+00	7.8457E+05		
		6	5.7546E+04	1.2922E+06	0.0000E+00	1.3497E+06		
		7	1.3421E+05	1.6662E+06	0.0000E+00	1.8004E+06		
	TOTAL						4.3553E+06	1.8126E+11
	TOTAL FOR BOTH LAKES						3.8108E+07	1.6907E+13

File: 4tab94.w51

Table 5. Areas, volume and fish estimates (%) in Kenai and Skilak Lakes, Alaska, night survey, September/October 1993.

	Skilak Lake		
Area	Surface Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^5$)	Number of Fish (%)
1	43.03 (43.5%)	1808.0 (28.9%)	55.2
2	33.46 (33.8%)	2674.0 (42.8%)	22.0
3	22.50 (22.7%)	1768.0 (28.3%)	22.8
Total	98.99 (100.0%)	6250.0 (100.0%)	100.0

	Kenai Lake		
Area	Surface Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)	Number of Fish (%)
1	7.72 (13.9%)	331.1 (8.0%)	8.6
2	11.91 (21.5%)	968.0 (23.5%)	25.4
3	10.54 (19.0%)	944.7 (23.0%)	8.8
4	14.37 (25.9%)	1205.0 (29.3%)	31.5
5	10.93 (19.7%)	666.0 (16.2%)	25.7
Total	55.47 (100.0%)	4114.8 (100.0%)	100.0

File: 5tab94.w51

Table 6. Estimated contribution of age-0 and age-1 sockeye salmon to the total fish population in Kenai and Skilak Lakes, Alaska, night survey, September/October 1993.

Location	Total Fish	Estimated Sockeye Salmon	Percent Age-0[a]	Total Age-0	Percent Age-1[a]	Total Age-1
Skilak Lake	33,753,100	33,073,500	94.8	31,346,700	5.2	1,726,800
Kenai Lake	4,355,300	4,346,500	99.87	4,340,700	0.13	5,900
Total[b]	38,108,400	37,420,000		35,687,400		1,732,700
Variance	1.6907E+13	1.6369E+13		1.4952E+13		2.7397E+11

[a] Age composition sample size for Skilak Lake = 2,879, for Kenai Lake = 2,979.
[b] Rounded to nearest 100 fish. File: 6tab94.w51

Table 7. Kenai Peninsula lakes' fall fry sockeye mean fork length and weight data.

Location		Age-0						Age-1					
		Length			Weight			Length			Weight		
	Year	(n)	(mm)	S.D.	(n)	(g)	S.D.	(n)	(mm)	S.D.	(n)	(g)	S.D.
Skilak													
	1986	15	57	n/a				8	74				
	1988	109	50	5.3	109	0.9	0.4						
	1989	136	50	3.3	136	1.2	0.3	126	64	6.0	126	2.8	0.7
	1990	928	49	4.3	290	1.3	0.3	34	72.8	3.3	20	4.0	0.4
	1991	863	51	4.9	286	1.5	0.5	55	73.8	3.8	14	4.7	0.5
	1992	883	54	6.0	883	1.8	0.6	10		3.6	10	7.0	0.8
	1993	3652	49	5.0	3652	1.2	0.4	55	75	5.0	55	4.5	0.9
	1994	687	50	3.9	687	1.4	0.4	110	68.3	3.7	110	3.6	0.6
Kenai													
	1986	227	52	n/a	227			2	77				
	1989	38	48	4.5	38	1.0	0.2	56	64	4.6	56	2.5	0.6
	1990	1484	52	4.6	1484	1.5	0.4	62	69.4	4.2	22	3.6	0.6
	1991	1364	53.5	6.5	1364	2.0	0.6	40	75.9	4.8	15	5.5	1.0
	1992	1492	56	7.3	1492	2.0	0.8	12	78	10.0	12	5.6	1.7
	1993	2969	45	4.0	2969	1.0	0.2	4	68	1.0	4	3.3	0.5
	1994	861	53.7	4.6	861	1.9	0.5	39	76.8	3.7	39	5.2	0.7
Tustumena													
	1980	222	59	6.1	222	2.3	0.7	20	80	3.5	20	5.7	0.7
	1981	197	55	5.1	197	1.6	0.4	21	73	4.6	21	3.8	0.7
	1982	194	54	5.1	194	1.8	0.5	17	74	3.9	17	4.0	0.9
	1983	562	60	6.1	562	2.5	0.7	55	80	5.0	55	5.8	1.1
	1984	388	61	4.6	388	2.5	0.6	186	79	3.7	186	5.3	0.8
	1985	173	56	5.6	173	2.1	0.6	52	78	5.0	52	5.6	1.2
	1986	156	50	6.4	156	1.3	0.5	92	73	4.5	92	4.1	0.7
	1987	143	53	5.9	143	1.8	0.6	50	71	3.8	50	4.2	0.6
	1988	303	55	5.3	303	1.8	0.5	89	75	3.6	89	4.5	0.6
	1989	47	52	5.7	47	1.9	0.6	18	74	4.6	18	5.1	0.9
	1990	200	57	5.5	200	1.5	0.4	50	75	2.9	50	3.4	0.5
	1991	202	57	5.4	202	2.0	0.5	47	78	6.5	47	5.1	1.2
	1992	323	59	4.4	323	2.0	0.4	21	79	4.1	21	4.52	0.7
	1993	417	63	6.7	417	2.9	0.8	46	81	3.0	46	6.18	0.7
	1994	318	64	5.0	318	2.6	0.6	76	82.7	3.0	76	5.5	0.5

Missing values indicate no data available. n = sample size; S. D. = 1 standard deviation. File: 7tab94.w51

Table 8. Estimated number of fish in Skilak Lake, Alaska, on 16 November 1993.

Lake	Area	Transect	Estimated Number of Fish: Surface	Midwater	Bottom	Area Total	Mean	Variance
Skilak	1	1	1.2320E+06	9.5400E+06	2.1745E+06	1.2947E+07		
		2	2.0409E+06	1.3407E+07	1.5619E+06	1.7010E+07		
		3	2.1635E+05	6.4590E+06	4.3184E+05	7.1072E+06	1.0211E+07	3.4067E+12
		4	4.0444E+05	1.0831E+07	8.9100E+05	1.2126E+07		
		5	3.8792E+05	4.6720E+06	5.4768E+05	5.6076E+06		
		1A	4.7983E+05	5.6140E+06	3.7533E+05	6.4692E+06		
	2	1	7.9611E+03	4.2100E+06	9.7858E+04	4.3158E+06		
		2	1.5077E+05	5.8360E+06	2.7847E+05	6.2652E+06	4.7344E+06	6.2598E+11
		3	1.6191E+05	3.2800E+06	1.8019E+05	3.6221E+06		
	3	1	9.9630E+05	1.5270E+07	3.4416E+06	1.9708E+07		
		2	2.3450E+05	1.8578E+07	1.7191E+06	2.0532E+07	1.4145E+07	1.4707E+13
		3	1.1900E+05	3.7400E+06	2.2750E+05	4.0865E+06		
		4	9.3690E+05	1.0632E+07	6.8514E+05	1.2254E+07		
	TOTAL						2.9091E+07	1.8740E+13

File: 8tab94.w51

Table 9. Areas, volume and fish estimates (%) in Skilak Lake, Alaska, night survey, November 1993.

	Skilak Lake		
Area	Surface Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)	Number of Fish (%)
1	43.03 (43.5%)	2217.0 (34.8%)	35.1
2	33.46 (33.8%)	2678.0 (42.1%)	16.3
3	22.50 (22.7%)	1470.0 (23.1%)	48.6
Total	98.99 (100.0%)	6365.0 (100.0%)	100.0

File: 9tab94.w51

Table 10. Estimated contribution of age-0 and age-1 sockeye salmon to the total fish population in Skilak Lake, Alaska, night survey, November 1993.

Location	Total Fish	Estimated Sockeye Salmon	Percent Age-0[a]	Total Age-0	Percent Age-1[a]	Total Age-1
Skilak Lake	29,091,000	28,135,400	98.1	27,608,400	1.9	527,000
Variance	1.8740E+13	1.7582E+13		1.6967E+13		4.360E+10

[a] Age composition sample size for Skilak Lake = 1,808; species composition sample size = 3,035
[b] Rounded to nearest 100 fish, file 10tab94.w51

Table 11. Estimated number of fish in Skilak Lake, Alaska, day survey, 25 April 1994.

			Estimated Number of Fish					
Lake	Area	Transect	Surface	Midwater	Bottom	Total	Area Mean	Variance
Skilak	1	1	5.2436E+05	2.5149E+06	0.0000E+00	3.0393E+06		
		2	7.7196E+05	7.0149E+06	0.0000E+00	7.7869E+06		
		3	1.9092E+05	5.6623E+06	0.0000E+00	5.8532E+06	5.9415E+06	5.5646E+11
		4	3.1046E+05	4.5780E+06	0.0000E+00	4.8885E+06		
		5	1.4419E+06	6.4150E+06	0.0000E+00	7.8569E+06		
		1A	8.2863E+04	6.1415E+06	0.0000E+00	6.2244E+06		
	2	1	2.5768E+04	4.6104E+05	0.0000E+00	4.8681E+05		
		2	1.6814E+04	4.3493E+05	0.0000E+00	4.5174E+05	6.5871E+05	3.5987E+10
		3	4.9106E+04	9.8847E+05	0.0000E+00	1.0376E+06		
	3	1	3.7253E+04	6.0719E+05	0.0000E+00	6.4444E+05		
		2	1.9359E+04	7.8655E+05	0.0000E+00	8.0591E+05	7.3955E+05	7.9936E+09
		3	4.4665E+04	9.1181E+05	0.0000E+00	9.5648E+05		
		4	9.4703E+04	4.5665E+05	0.0000E+00	5.5135E+05		
	TOTAL						7.3398E+06	6.0044E+11

No bottom estimate was made; file: 11tab94.w51

Table 12. Areas, volume and fish estimates (%) in Skilak Lake, Alaska, day survey, 25 April 1994.

	Skilak Lake		
Area	Surface Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)	Number of Fish (%)
1	43.03 (43.5%)	2631.0 (38.1%)	80.9
2	33.46 (33.8%)	2712.0 (39.3%)	9.0
3	22.50 (22.7%)	1564.0 (22.6%)	10.1
Total	98.99 (100.0%)	6365.0 (100.0%)	100.0

File: 12tab94.w51

Table 13. Estimated number of fish in Skilak Lake, Area 1, Alaska, on 29 April 1994.

Lake	Area	Transect	Estimated Number of Fish Surface	Midwater	Bottom[a]	Total	Area Mean	Variance
Skilak	1	1a	1.1228E+06	9.6880E+06	0.0000E+00	1.0811E+07		
		2	2.4566E+06	1.0733E+07	0.0000E+00	1.3190E+07		
		3	2.7741E+06	1.7090E+07	0.0000E+00	1.9864E+07	1.8178E+07	7.0595E+12
		4	2.6967E+06	1.9756E+07	0.0000E+00	2.2453E+07		
		5	2.4475E+06	2.2127E+07	0.0000E+00	2.4575E+07		

[a] No estimate was made for fish near the bottom; file: 13tab94.w51

Table 14. Estimated contribution of age-1 and age-2 sockeye salmon to the total fish population in Skilak Lake, Area 1, Alaska, night survey, 29 April, 1994.

Location	Total Fish	Estimated Sockeye Salmon	Percent Age-1[a]	Total Age-1	Percent Age-2[a]	Total Age-2
Skilak Lake	18,178,000	17,832,400	86.2	15,375,800	13.8	2,456,600
Variance	7.0596E+12	6.7966E+12		5.1752E+12		2.5123E+11

[a] Age composition sample size for Skilak Lake = 306; species composition sample size = 1,736
[b] Rounded to nearest 100 fish, file 14tab94.w51

Table 15. Estimated number of fish in Skilak and Kenai Lakes, Alaska, September 1994.

Lake	Area	Transect	Estimated Number of Fish: Surface	Midwater	Bottom	Total	Area Mean	Variance
Skilak	1	1	3.1885E+05	5.4550E+06	4.7069E+05	6.2445E+06		
		2	9.8354E+04	2.8210E+06	1.3733E+05	3.0567E+06		
		3	7.2536E+04	3.3389E+06	1.8145E+05	3.5929E+06	4.1387E+06	2.9813E+11
		4	1.8602E+05	2.6739E+06	1.7032E+05	3.0302E+06		
		5	3.0194E+05	2.9170E+06	3.3674E+05	3.5557E+06		
		6	6.5604E+05	4.2440E+06	4.5197E+05	5.3520E+06		
	2	1	5.5430E+04	1.2753E+06	1.8853E+04	1.3496E+06		
		2	1.2517E+05	2.1545E+06	1.0430E+04	2.2901E+06	3.8348E+06	3.5614E+12
		3	4.4237E+04	2.1655E+06	3.0680E+04	2.2404E+06		
		4	1.1694E+05	8.8981E+06	4.4405E+05	9.4591E+06		
	3	1	3.1334E+05	7.1764E+05	8.2635E+04	1.1136E+06		
		2	5.0659E+05	2.4572E+06	5.5101E+03	2.9693E+06	1.5939E+06	2.1068E+11
		3	1.1414E+05	1.0592E+06	2.3922E+04	1.1973E+06		
		4	4.1776E+04	1.0023E+06	5.1406E+04	1.0955E+06		
	TOTAL						9.5674E+06	4.0702E+12
Kenai	1	1	4.5440E+02	6.8480E+05	5.1831E+04	7.3709E+05		
		2	0.0000E+00	5.7118E+05	8.7262E+04	6.5844E+05		
		3	1.9554E+03	5.7934E+05	6.1039E+04	6.4233E+05	9.6855E+05	6.8088E+10
		4	3.1173E+05	1.6255E+06	2.9041E+05	2.2276E+06		
		5	0.0000E+00	4.6916E+05	5.4113E+04	5.2327E+05		
		6	1.8602E+03	9.3909E+05	8.1590E+04	1.0225E+06		
	2	1	3.5873E+03	2.2141E+05	0.0000E+00	2.2500E+05		
		2	7.9642E+03	5.5516E+05	0.0000E+00	5.6312E+05		
		3	0.0000E+00	1.3950E+06	0.0000E+00	1.3950E+06	7.7715E+05	6.2868E+10
		4	0.0000E+00	9.2546E+05	0.0000E+00	9.2546E+05		
	3	1	2.0151E+04	5.1343E+05	0.0000E+00	5.3358E+05		
		2	4.3667E+02	6.3860E+05	0.0000E+00	6.3904E+05		
		3	1.5718E+04	7.8709E+05	0.0000E+00	8.0281E+05	5.5970E+05	7.4753E+09
		4	0.0000E+00	5.5212E+05	0.0000E+00	5.5212E+05		
		5	1.4090E+04	2.5687E+05	0.0000E+00	2.7096E+05		
	4	1	6.4158E+02	6.3374E+05	0.0000E+00	6.3438E+05		
		2	9.2598E+01	5.2835E+05	0.0000E+00	5.2844E+05		
		3	4.7005E+04	6.7096E+05	0.0000E+00	7.1797E+05	6.4088E+05	1.4365E+09
		4	0.0000E+00	5.9387E+05	0.0000E+00	5.9387E+05		
		5	6.6306E+03	7.2310E+05	0.0000E+00	7.2973E+05		
	TOTAL						2.9463E+06	1.3987E+11
	TOTAL FOR BOTH LAKES						1.2514E+07	4.2101E+12

File 15tab94.w51

Table 16. Areas, volume and fish estimates (%) in Kenai and Skilak Lakes, Alaska, night survey, September/October 1994.

	Skilak Lake		
Area	Surface Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)	Number of Fish (%)
1	43.03 (43.5%)	2120.0 (33.8%)	43.3
2	33.46 (33.8%)	2666.0 (42.5%)	40.1
3	22.50 (22.7%)	1491.0 (23.7%)	16.6
Total	98.99 (100.0%)	6277.0 (100.0%)	100.0

	Kenai Lake		
Area	Surface Area ($m^2 \times 10^6$)	Volume ($m^3 \times 10^6$)	Number of Fish (%)
1	7.72 (13.9%)	316.0 (7.3%)	32.9
2	11.91 (21.5%)	951.0 (22.1%)	26.4
3	10.54 (19.0%)	888.0 (20.6%)	19.0
4	25.30 (25.9%)	2150.0 (50.0%)	21.7
Total	55.47 (100.0%)	4305.0 (100.0%)	100.0

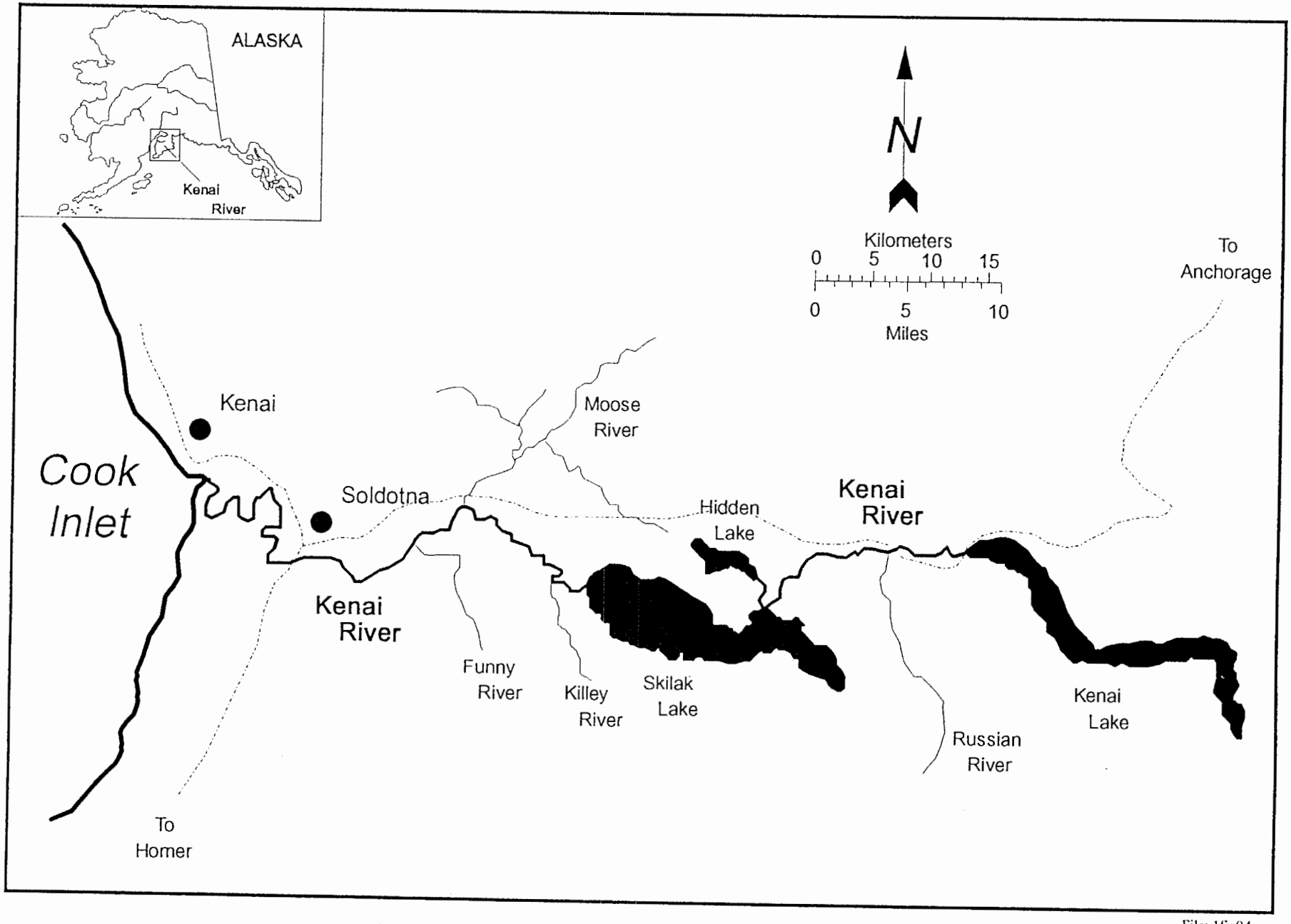
File: 16tab94.w51

Table 17. Estimated contribution of age-0 and age-1 sockeye salmon to the total fish population in Kenai and Skilak Lakes, Alaska, night survey, September/October 1994.

Location	Total Fish	Estimated Sockeye Salmon	Percent Age-0[a]	Total Age-0	Percent Age-1[a]	Total Age-1
Skilak Lake	9,567,400	9,510,300	87.8	8,353,900	12.2	1,156,500
Kenai Lake	2,946,300	2,931,600	95.7	2,805,600	4.3	126,000
Total[b]	12,513,700	12,441,900	89.7	11,159,500	10.3	1,282,500
Variance	4.2101E+12	4.1604E+12		3.2452E+12		7.4078E+10

[a] Age composition sample size for Skilak Lake = 797; for Kenai Lake = 900. Species composition sample size for Skilak Lake = 2020

[b] Rounded to nearest 100 fish. File 17tab94.w51



File: 1fig94.pre

Figure 1. Map of the Kenai River drainage

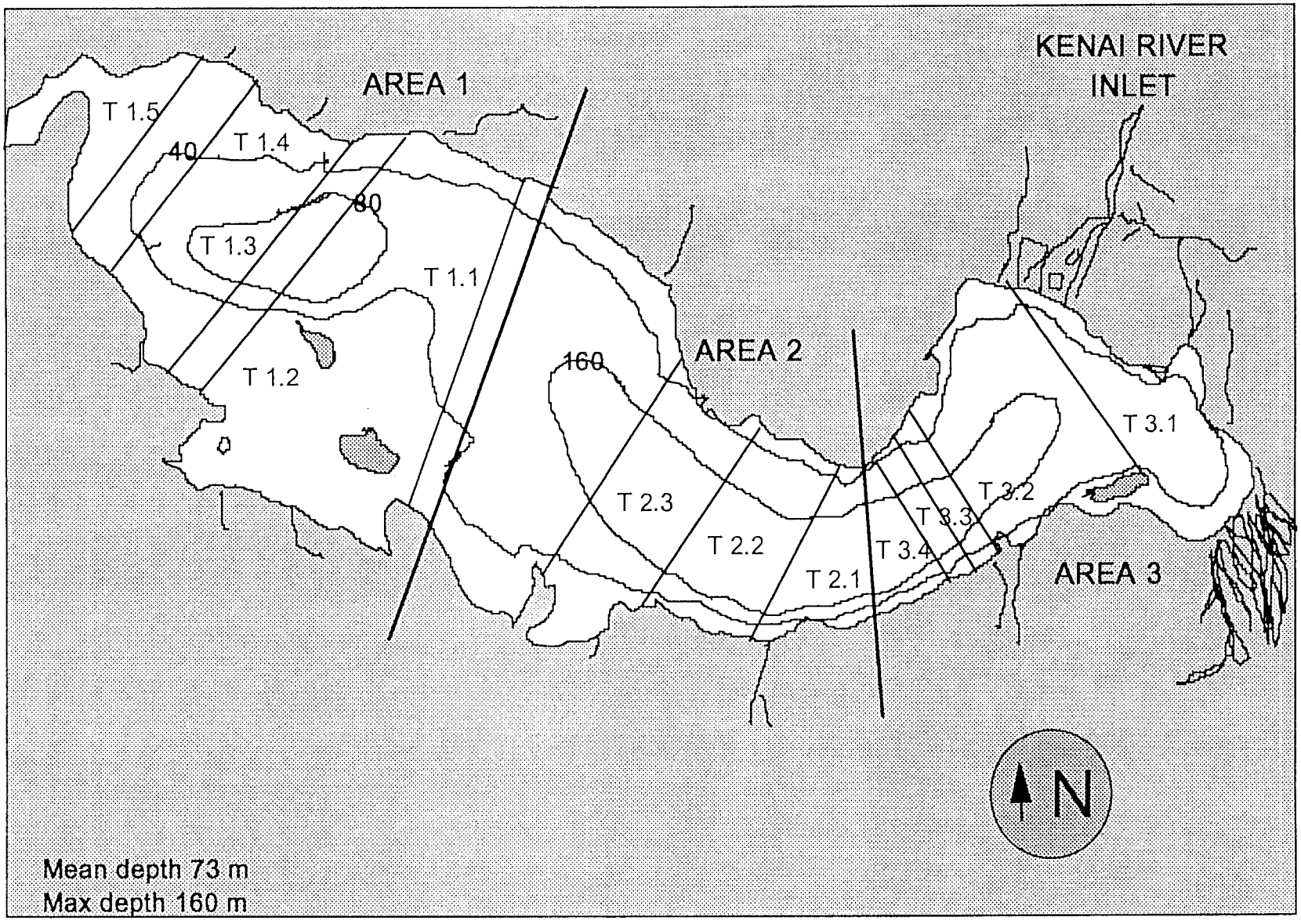
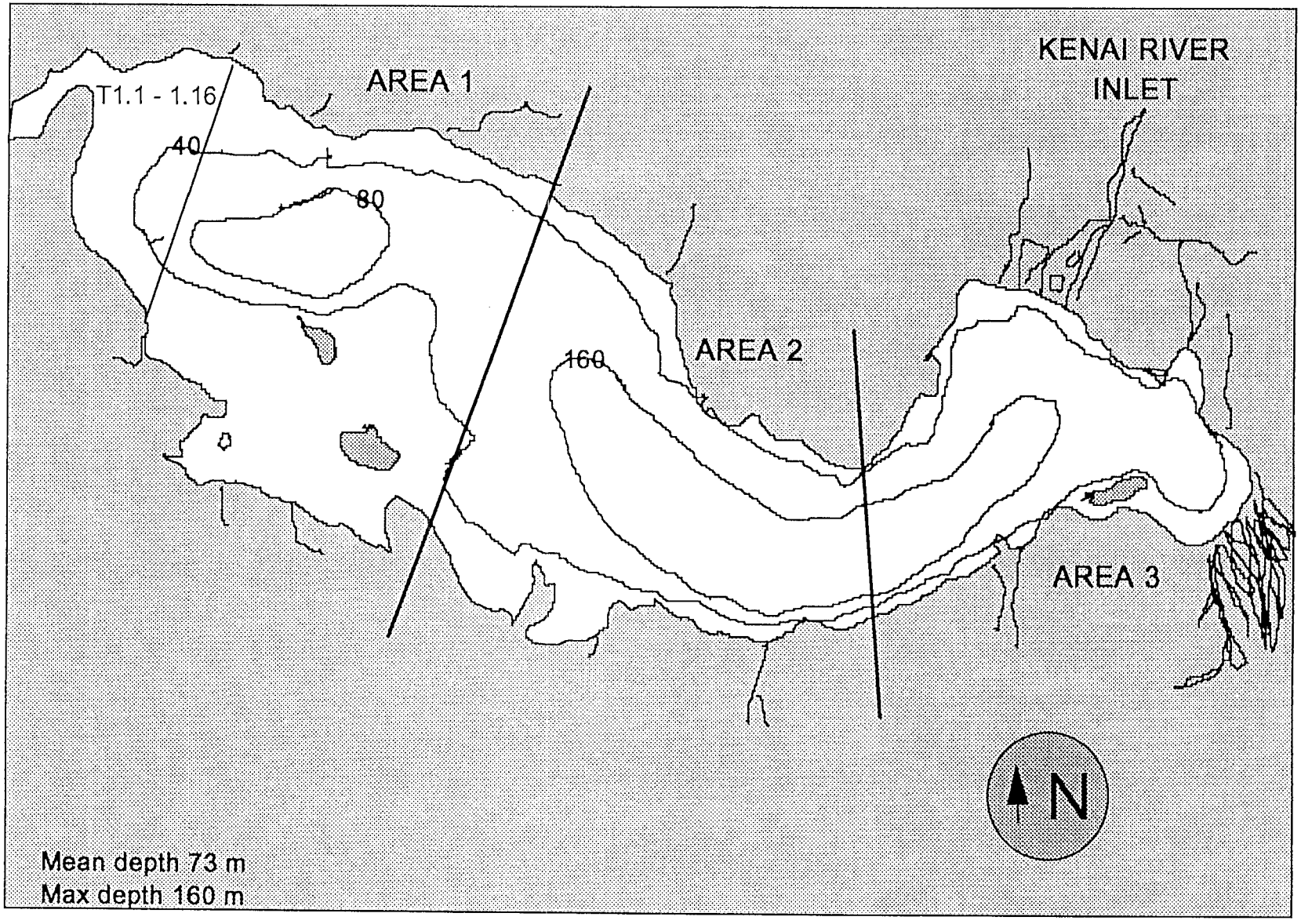
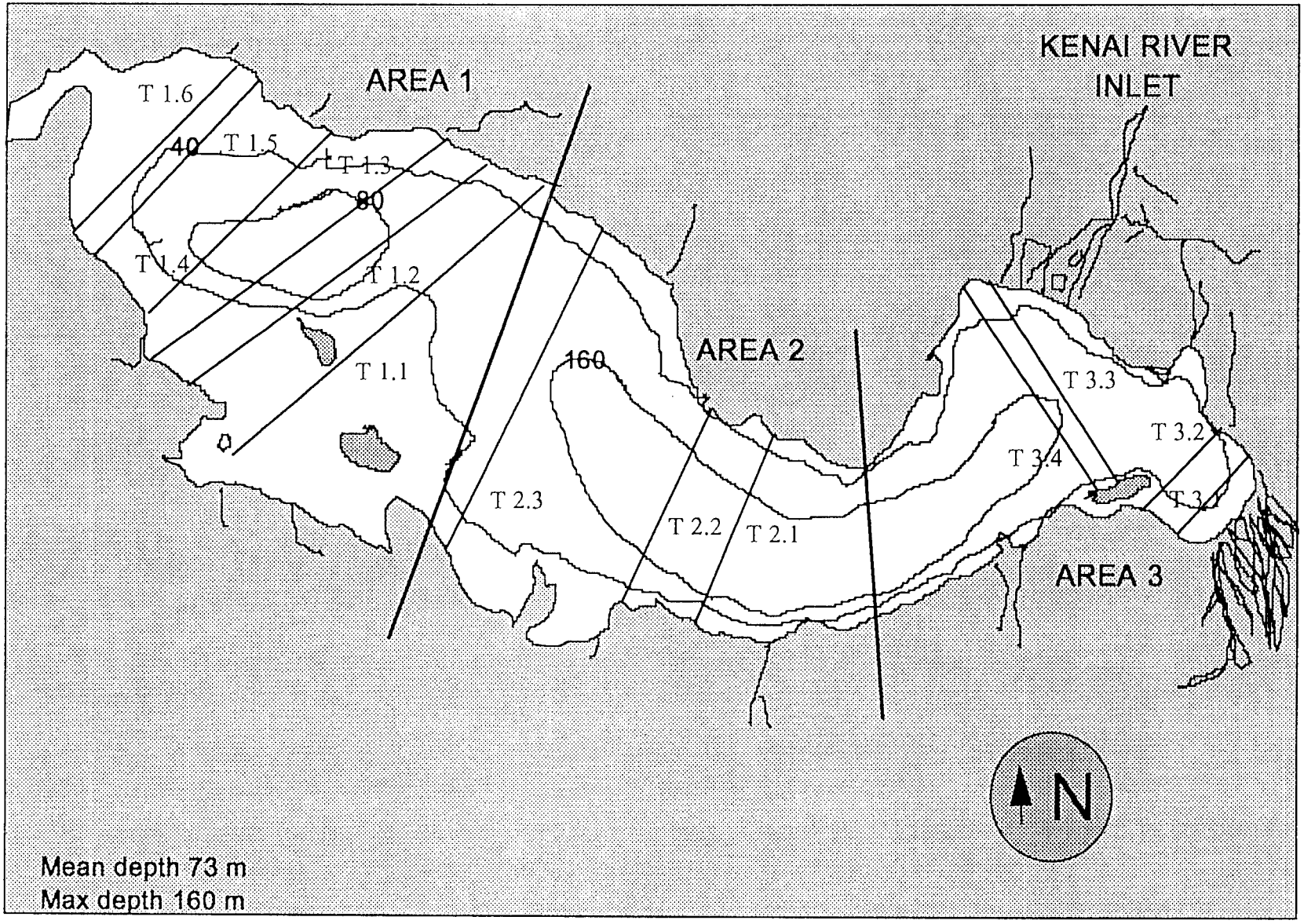


Figure 2 . Hydroacoustic transects conducted in Skilak Lake, Alaska on 5 May 1993.



File: 3fig94.pre

Figure 3. Hydroacoustic transects conducted in Skilak Lake, Alaska on 8 May 1993. (Note : a single transect was repeated 16 times)



File: 4fig94.pre

Figure 4. Hydroacoustic transects conducted in Skilak Lake, Alaska on 26 September 1993.

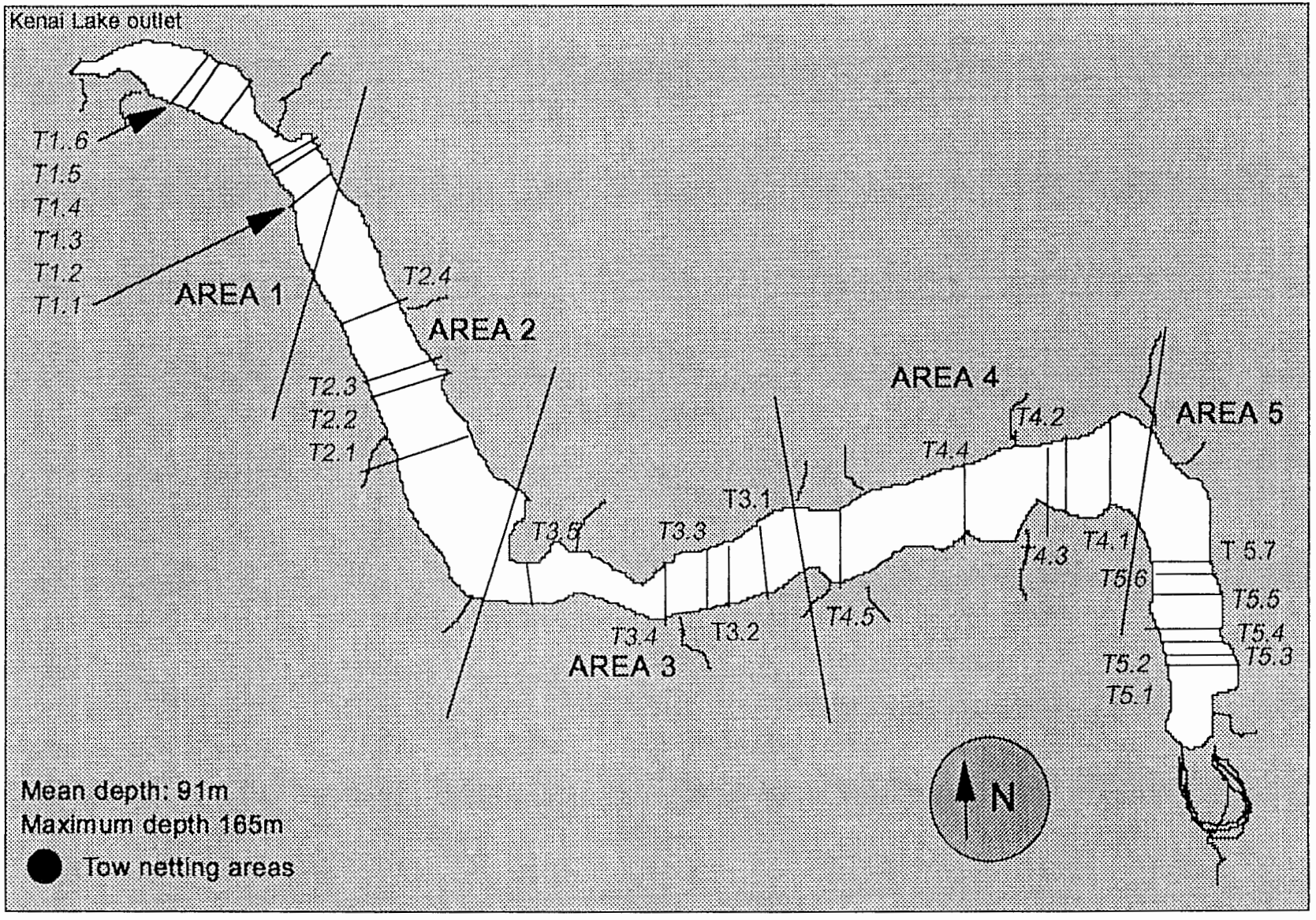
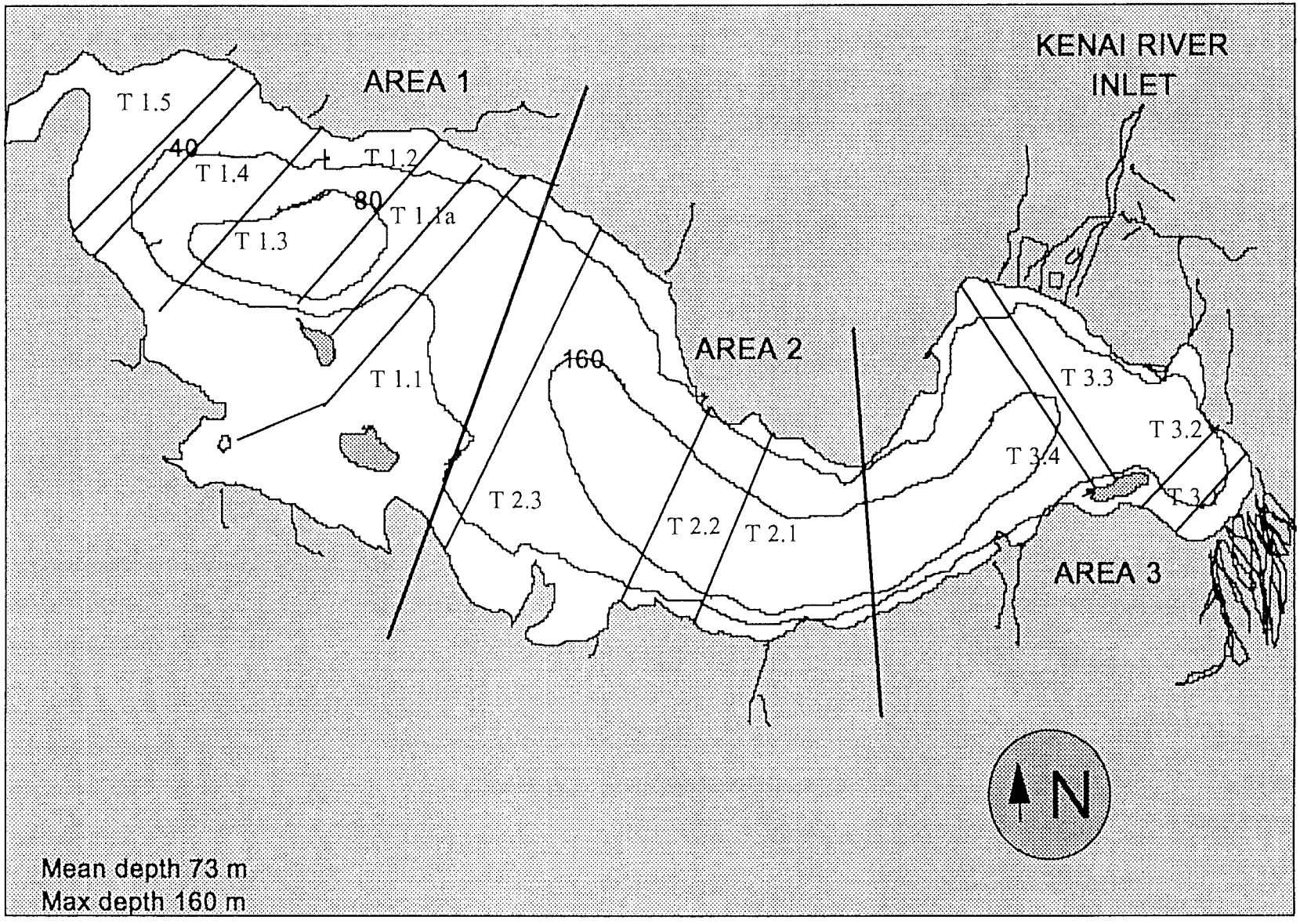
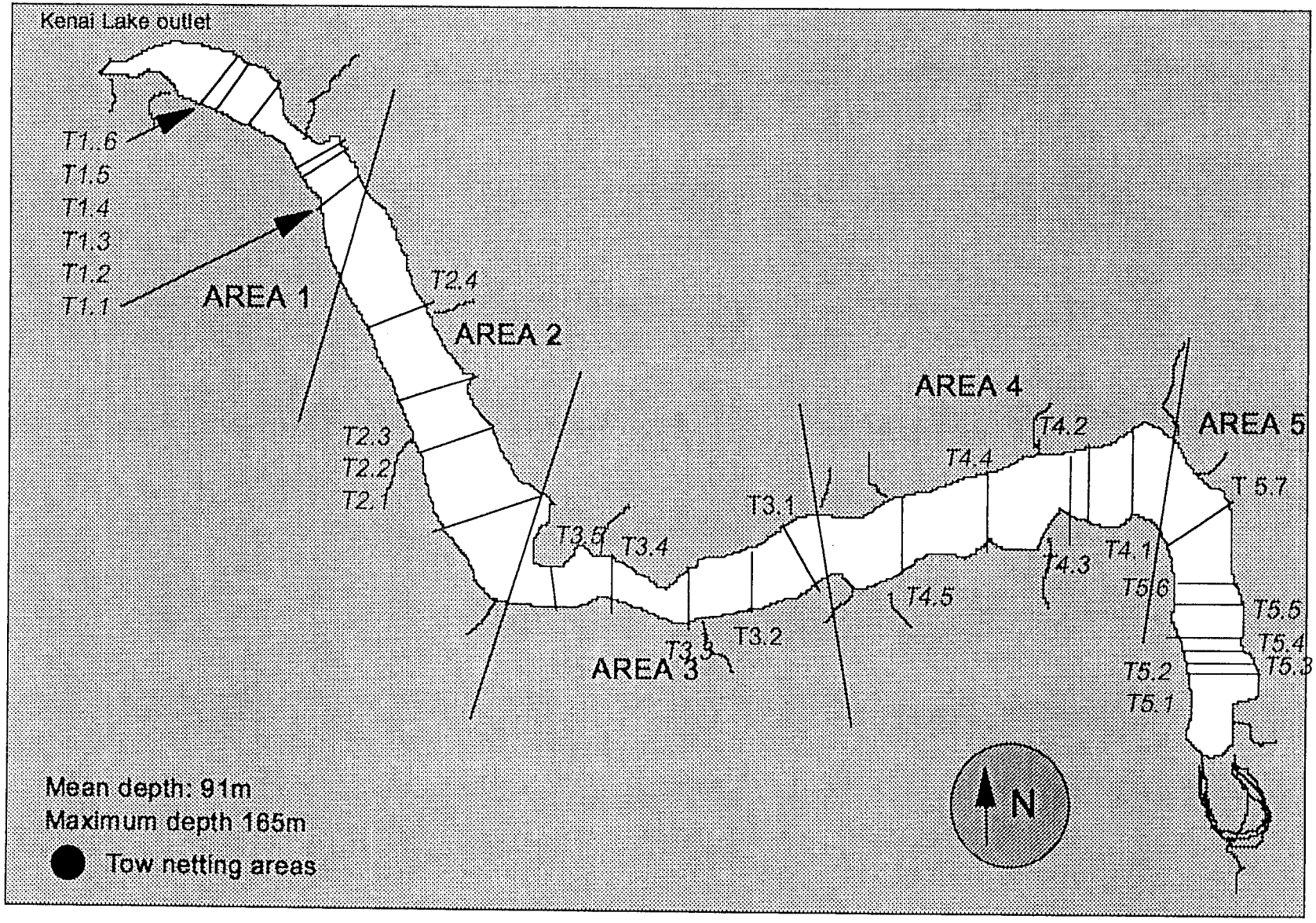


Figure 5. Hydroacoustic transects conducted in Kenai Lake, Alaska on 4 October 1993.



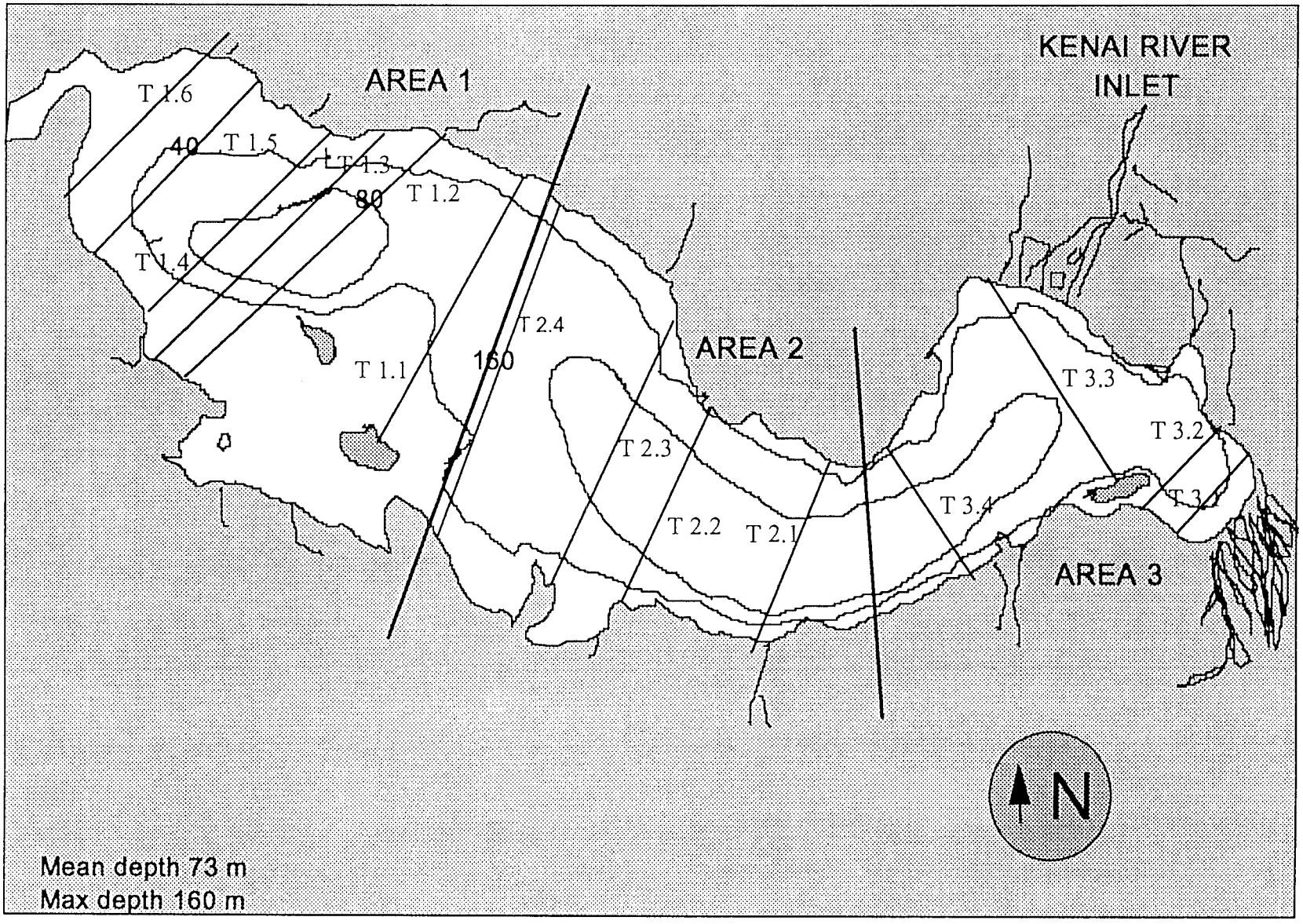
File: 6fig94.pre

Figure 6. Hydroacoustic transects conducted in Skilak Lake, Alaska on 16 & 18 November 1993.



File: 7fig94.pre

Figure 7. Hydroacoustic transects conducted in Kenai Lake, Alaska on 7 October 1994.



File: 8fig94.pre

Figure 8. Hydroacoustic transects conducted in Skilak Lake, Alaska on 27 September 1994.

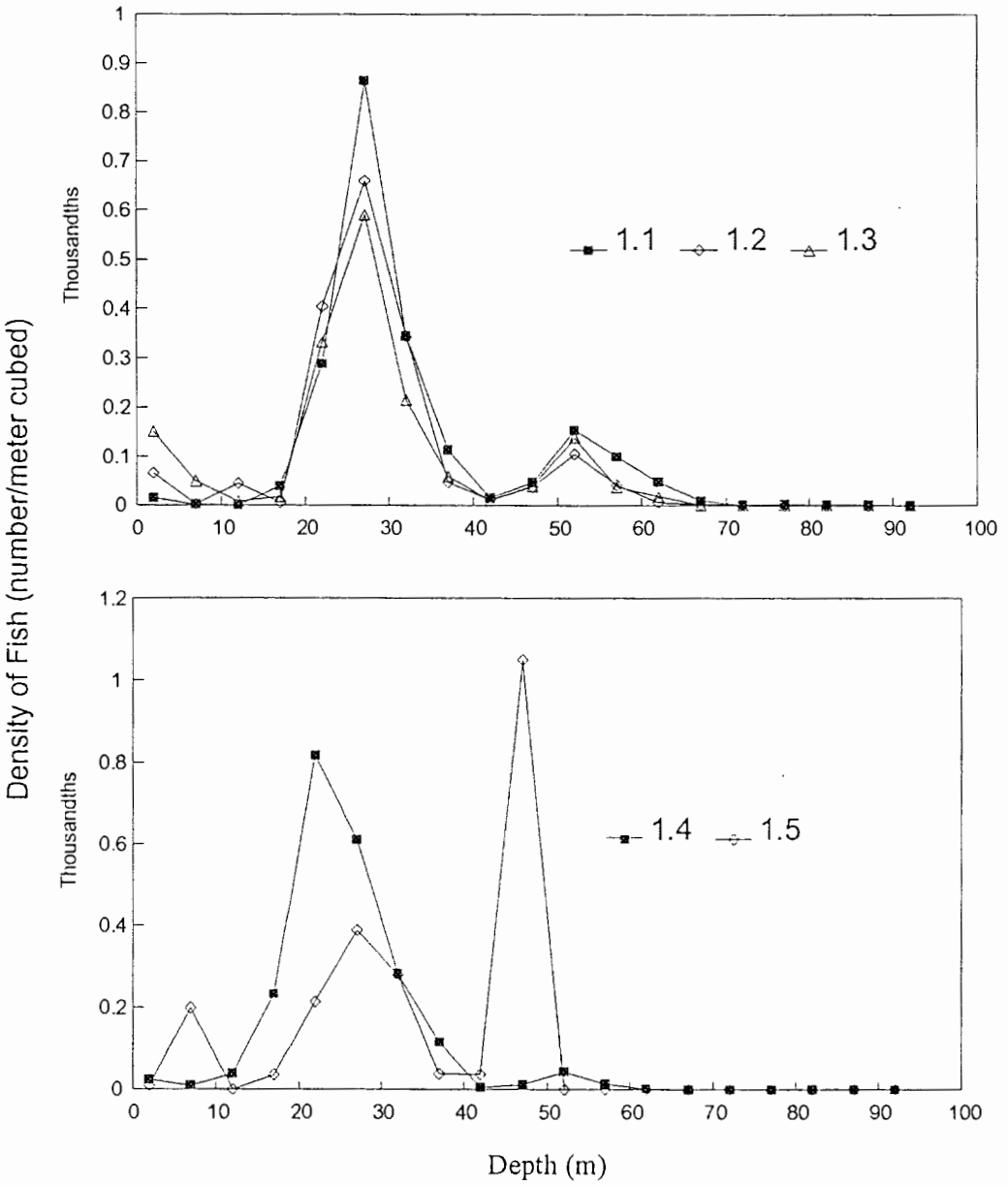


Figure 9. Density of fish in Skilak Lake, Area 1 during a day survey on 5 May 1993.

File: 9fig94.pre

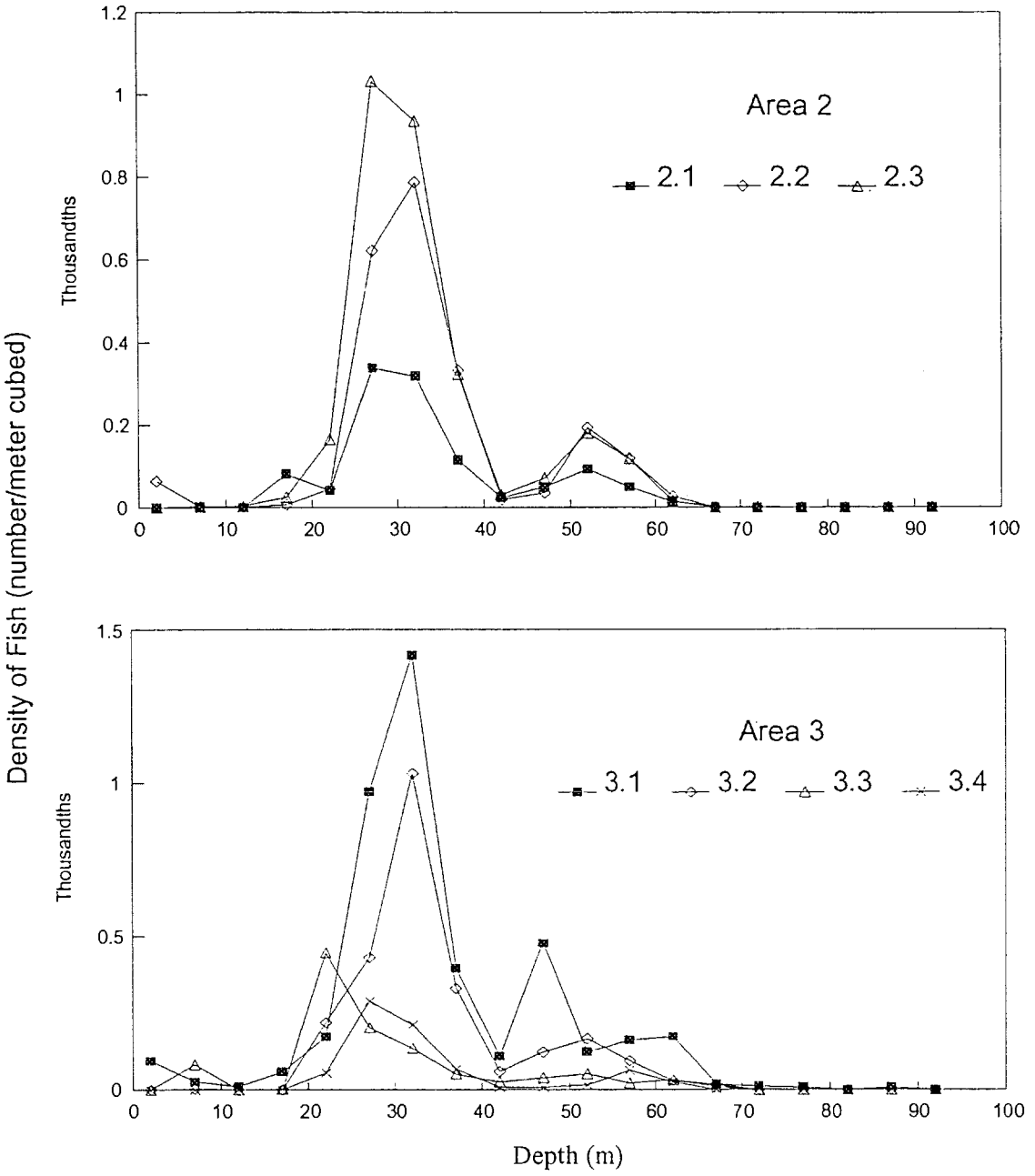


Figure 10. Density of fish in Skilak Lake, Areas 2 and 3, during a day survey on 5 May 1993.

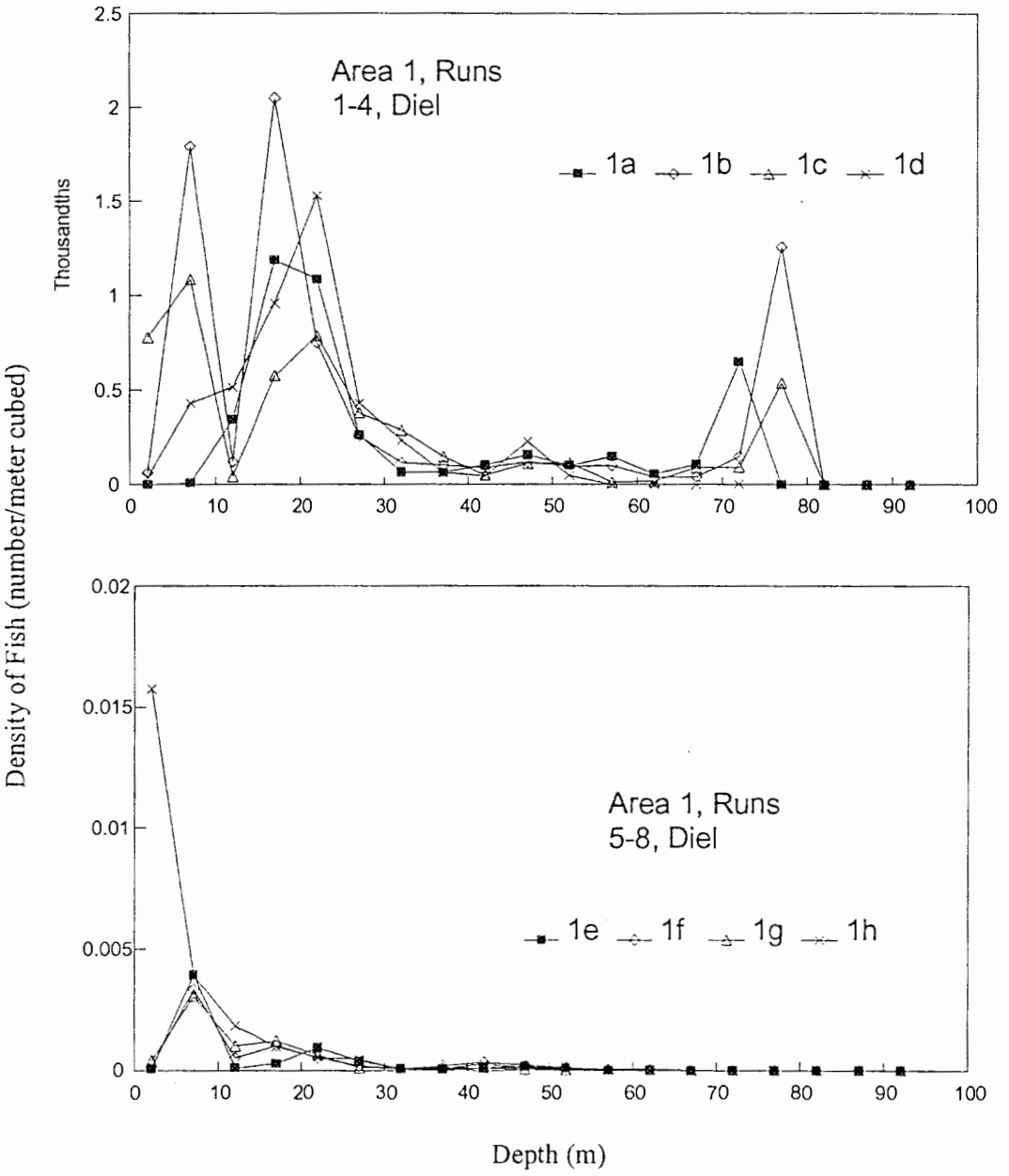


Figure 11. Density of fish in Skilak Lake, Area 1, runs 1 - 8, during diel studies conducted on 8 May 1993.

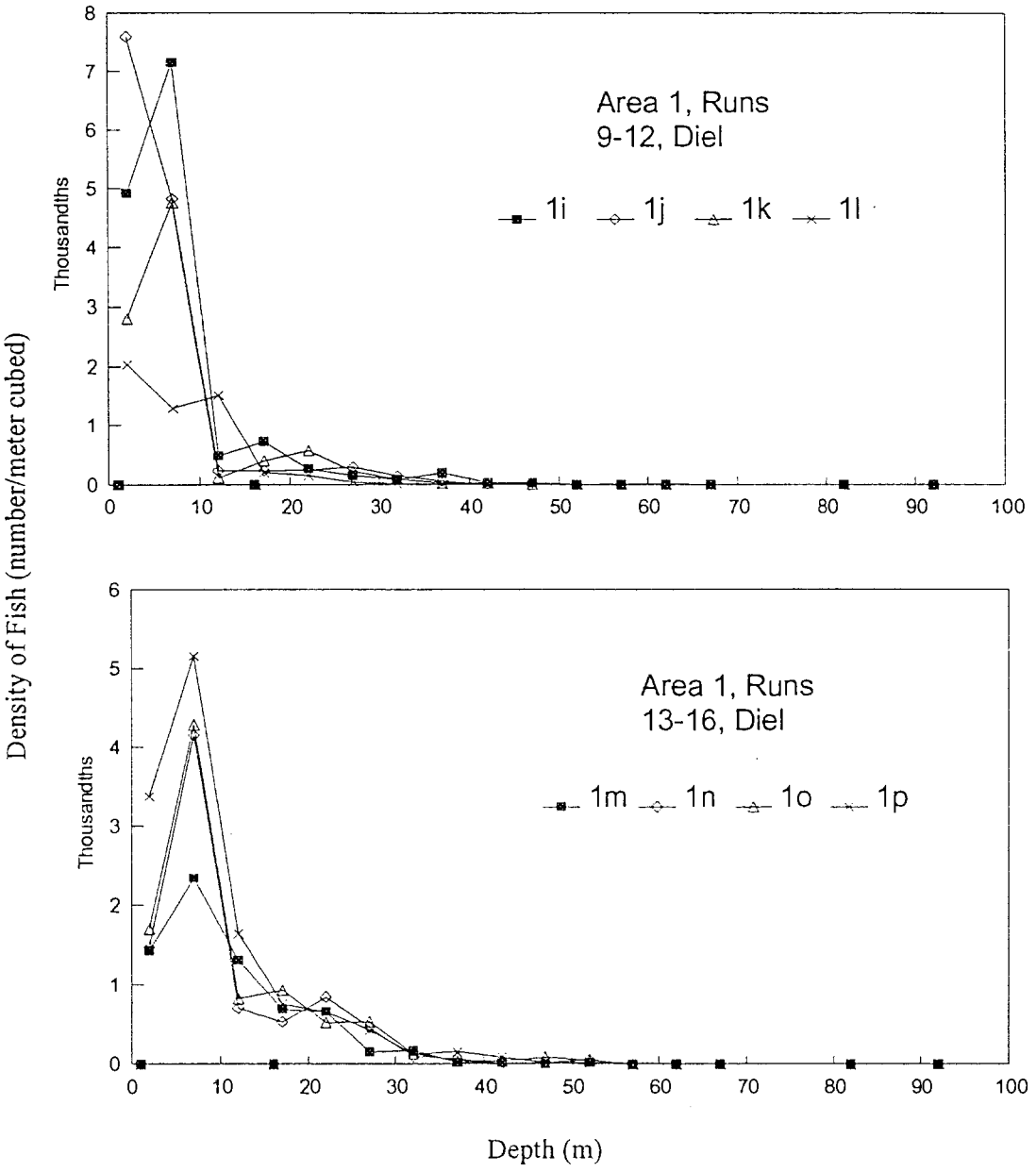


Figure 12. Density of fish in Skilak Lake, Area 1, runs 9-16, during diel studies conducted on 8 May 1993.

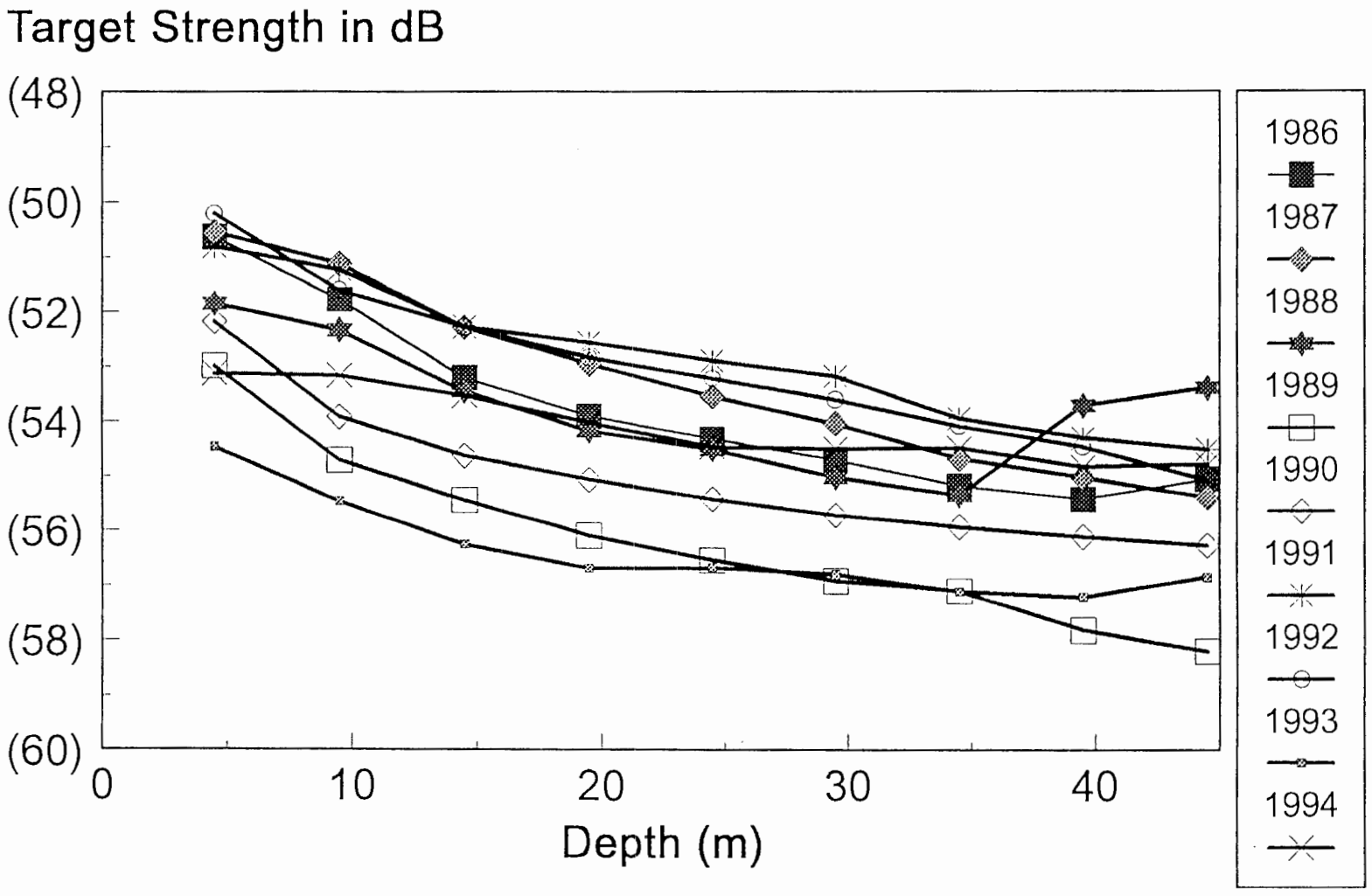


Figure 13. Fish target strength measured in Skilak Lake, Alaska in September, 1986-1994.

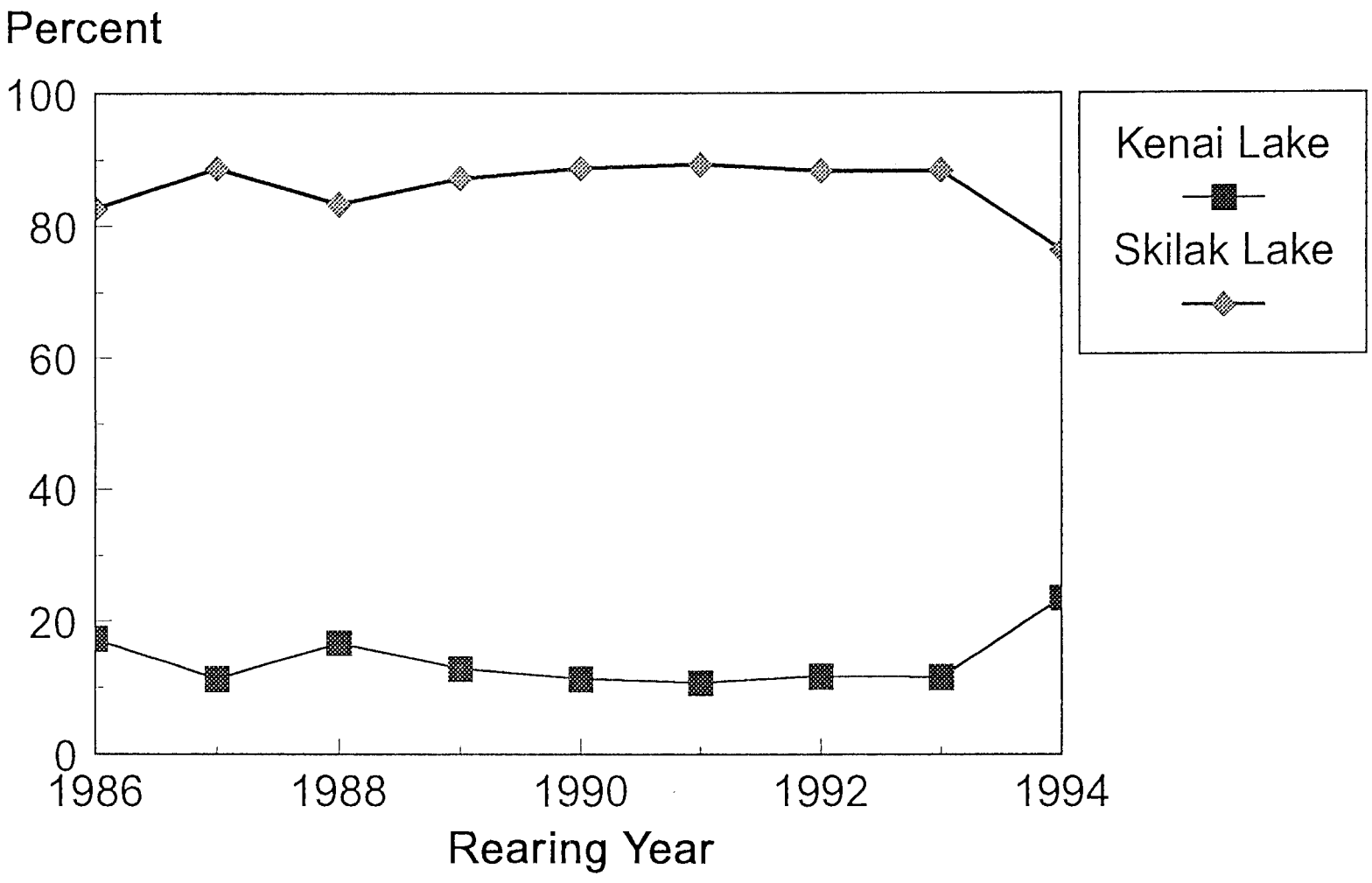


Figure 14. Relative distribution of juvenile sockeye in the Kenai River system, Alaska 1986-1994.

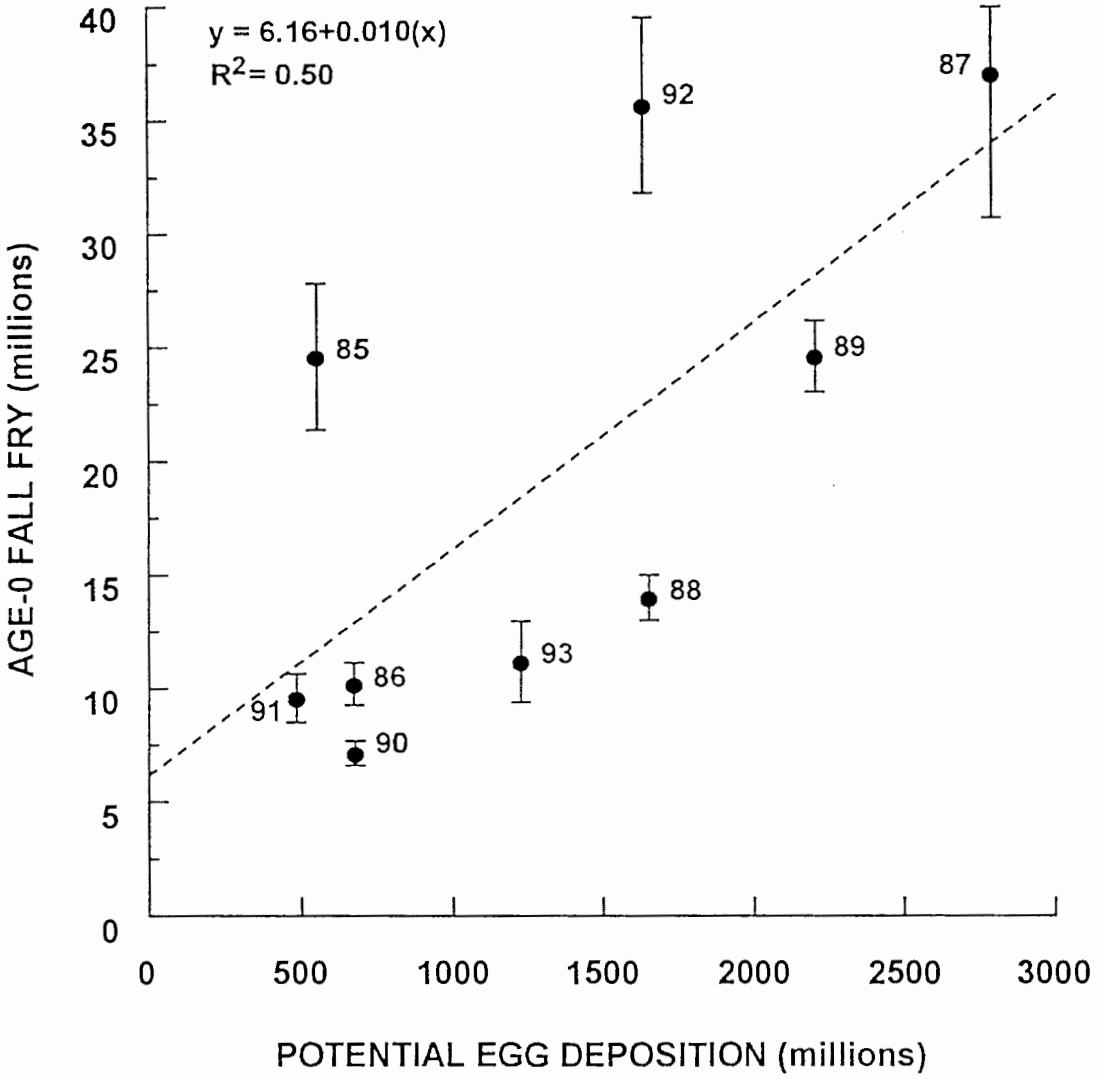


Figure 15. Relationship between the number of age-0 sockeye salmon fall fry in Kenai and Skilak Lakes and potential egg deposition by mainstem spawners. Values listed indicate brood year of the eggs and fry. Vertical bars are standard errors of estimated fry abundances.

APPENDIX

Appendix A.1. Calibration and processing parameters used in collection and analysis of Kenai and Skilak Lake, Alaska hydroacoustic data, 1993-1994.

Date	Source Level (dB)	Receiving Sensitivity 1 (dB)	Receiving Sensitivity 2 (dB)	Gain (dB)	Threshold (mv)	Wide Beam Dropoff (dB)	Narrow Beam Pattern Factor	A Coefficient	B Coefficient	Bottom Threshold (mv)
May 1993	217.66	-165.77	-165.67	0	200	1.346	.1052e-02	1.289	.610	9000
Sept 1993-Nov. 1993	216.74	-165.75	-165.39	6	200	1.310	.1093e-02	1.883	.467	9000
April 1994	216.74	-165.75	-165.39	6	200	1.310	.1093e-02	1.883	.467	7000
Sept. 1994	21.7	-166.86	-167.12	6	300	1.180	.1010e-02	1.919	.424	9000

File: 1aptab94.w51

Appendix A.2. Average backscattering cross section (sigma) and target strength data by depth strata for Skilak Lake, Alaska, 5 May 1993.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	8	.1672E-03	.1928E-03	-42.69	8.90
7.0 - 12.0	26	.1331E-03	.3469E-03	-48.92	10.21
12.0 - 17.0	21	.1317E-03	.3027E-03	-48.23	10.36
17.0 - 22.0	89	.5326E-04	.1248E-03	-48.96	7.82
22.0 - 27.0	379	.2058E-04	.5907E-04	-51.90	6.27
27.0 - 32.0	2500	.1249E-04	.8160E-04	-53.65	5.29
32.0 - 37.0	3475	.6944E-05	.2007E-04	-54.55	4.71
37.0 - 42.0	2389	.7069E-05	.6088E-04	-55.26	4.36
42.0 - 47.0	1298	.1546E-04	.1241E-03	-55.21	4.86
47.0 - 52.0	1261	.4741E-05	.2143E-04	-56.17	3.93
52.0 - 57.0	2120	.3206E-05	.3563E-05	-56.60	3.72
57.0 - 62.0	1849	.3569E-05	.4285E-05	-56.37	3.98
62.0 - 67.0	893	.5643E-05	.6651E-05	-54.64	4.40
67.0 - 72.0	197	.7019E-05	.8129E-05	-53.83	4.57
72.0 - 77.0	42	.5159E-05	.4050E-05	-54.30	3.89
77.0 - 82.0	41	.5239E-05	.5331E-05	-55.08	4.88
82.0 - 87.0	2	.1197E-05	.8813E-05	-59.90	3.54
87.0 - 92.0	3	.2477E-05	.1283E-05	-56.42	2.09
92.0 - 97.0	0	.0000E-00	.0000E-00	-00.00	0.00
Total	16593	.8556E-05	.5848E-04	-55.04	4.76

[a] Target strength determined from dual-beam data collected *in situ*. File: 2aptab94.w51

Appendix A.3. Average backscattering cross section (sigma) and target strength data by depth strata for Skilak Lake, Alaska, 8 May 1993.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	301	.2332E-04	.3785E-04	-49.45	5.75
7.0 - 12.0	1183	.1868E-04	.5008E-04	-50.71	5.33
12.0 - 17.0	845	.2067E-04	.9690E-04	-52.13	5.70
17.0 - 22.0	1480	.1060E-04	.3701E-04	-53.38	5.17
22.0 - 27.0	2263	.6761E-05	.1002E-04	-54.19	4.81
27.0 - 32.0	1528	.5628E-05	.8322E-05	-54.98	4.65
32.0 - 37.0	703	.4614E-05	.5427E-05	-55.30	4.25
37.0 - 42.0	645	.4540E-05	.4617E-05	-55.36	4.31
42.0 - 47.0	712	.3925E-05	.6865E-05	-56.32	4.24
47.0 - 52.0	1088	.3367E-05	.2986E-05	-56.18	3.66
52.0 - 57.0	600	.4214E-05	.4396E-05	-55.69	4.19
57.0 - 62.0	161	.6920E-05	.7092E-05	-53.96	4.79
62.0 - 67.0	81	.5323E-05	.4973E-05	-54.35	4.01
67.0 - 72.0	33	.4046E-05	.2856E-05	-55.14	3.56
72.0 - 77.0	10	.4626E-05	.2205E-05	-53.91	2.47
77.0 - 82.0	2	.2660E-05	.2585E-05	-57.14	5.18
82.0 - 87.0	0	.0000E-00	.0000E-00	-00.00	0.00
87.0 - 92.0	0	.0000E-00	.0000E-00	-00.00	0.00
92.0 - 97.0	0	.0000E-00	.0000E-00	-00.00	0.00
Total	11635	.8858E-05	.3493E-04	-54.09	5.09

[a] Target strength determined from dual-beam data collected *in situ*. File: 3aptab94.w51

Appendix A.4. Average backscattering cross section (sigma) and target strength data by depth strata for Kenai Lake, Alaska, 4 October 1993.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	198	.1122E-04	.4837E-04	-55.52	7.32
7.0 - 12.0	541	.7691E-05	.1892E-04	-56.54	7.24
12.0 - 17.0	2233	.5728E-05	.1919E-04	-57.16	6.48
17.0 - 22.0	5501	.4197E-05	.6045E-05	-57.13	5.93
22.0 - 27.0	9171	.3710E-05	.4349E-05	-57.32	5.61
27.0 - 32.0	9963	.3404E-05	.3610E-05	-57.40	5.38
32.0 - 37.0	7885	.2917E-05	.3935E-05	-57.92	5.08
37.0 - 42.0	4362	.2631E-05	.2526E-05	-57.96	4.78
42.0 - 47.0	2104	.2518E-05	.2551E-05	-58.09	4.65
47.0 - 52.0	1184	.2163E-05	.1927E-05	-58.44	4.28
52.0 - 57.0	707	.1798E-05	.1532E-05	-59.19	4.26
57.0 - 62.0	465	.1778E-05	.1822E-05	-59.39	4.28
62.0 - 67.0	250	.1790E-05	.1565E-05	-59.07	4.00
67.0 - 72.0	137	.1511E-05	.1226E-05	-59.45	3.45
72.0 - 77.0	56	.1666E-05	.1151E-05	-59.22	4.02
77.0 - 82.0	28	.1598E-05	.1191E-05	-59.23	3.56
82.0 - 87.0	21	.1414E-05	.1971E-05	-60.45	3.75
87.0 - 92.0	5	.6158E-04	.9034E-04	-52.55	13.29
92.0 - 97.0	2	.1831E-05	.8386E-06	-57.61	2.06
Total	44813	.3476E-05	.7090E-05	-57.60	5.41

[a] Target strength determined from dual-beam data collected *in situ*. File: 4aptab94.w51

Appendix A.5. Average backscattering cross section (sigma) and target strength data by depth strata for Skilak Lake, Alaska, 26 September 1993.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	1438	.9673E-05	.2355E-04	-54.47	6.67
7.0 - 12.0	5619	.7465E-05	.1159E-04	-55.46	6.61
12.0 - 17.0	13195	.5427E-05	.8170E-05	-56.25	6.14
17.0 - 22.0	25486	.4469E-05	.5374E-05	-56.69	5.83
22.0 - 27.0	30573	.4168E-05	.5255E-05	-56.68	5.54
27.0 - 32.0	26860	.3846E-05	.4472E-05	-56.80	5.29
32.0 - 37.0	17410	.3428E-05	.4083E-05	-57.11	5.07
37.0 - 42.0	8279	.3301E-05	.4583E-05	-57.21	4.95
42.0 - 47.0	3645	.3993E-05	.1239E-04	-56.85	5.09
47.0 - 52.0	2817	.3735E-05	.5015E-05	-56.89	5.04
52.0 - 57.0	1523	.3992E-05	.5051E-05	-56.47	4.91
57.0 - 62.0	774	.3914E-05	.4392E-05	-56.27	4.69
62.0 - 67.0	464	.4057E-05	.4542E-05	-56.49	5.06
67.0 - 72.0	290	.4547E-05	.4753E-05	-55.63	4.72
72.0 - 77.0	134	.3985E-05	.3621E-05	-55.59	3.99
77.0 - 82.0	77	.4141E-05	.4688E-05	-56.11	4.77
82.0 - 87.0	59	.2517E-05	.2263E-05	-57.74	4.33
87.0 - 92.0	39	.3679E-05	.4112E-05	-56.65	5.01
92.0 - 97.0	5	.8688E-06	.5658E-06	-62.14	5.11
Total	138697	.4309E-05	.6501E-05	-56.68	5.56

[a] Target strength determined from dual-beam data collected *in situ*. File: 5aptab94.w51

Appendix A.6. Average backscattering cross section (sigma) and target strength data by depth strata for Skilak Lake, Alaska, 16 November 1993.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	547	.7928E-05	.1173E-04	-55.29	6.44
7.0 - 12.0	2870	.6346E-05	.9945E-05	-56.28	6.49
12.0 - 17.0	5770	.5229E-05	.7589E-05	-57.01	6.32
17.0 - 22.0	12136	.4474E-05	.5433E-05	-56.87	5.97
22.0 - 27.0	14149	.4441E-05	.5270E-05	-56.57	5.74
27.0 - 32.0	13272	.4247E-05	.4717E-05	-56.41	5.40
32.0 - 37.0	11717	.4063E-05	.4345E-05	-56.41	5.19
37.0 - 42.0	8548	.3810E-05	.3842E-05	-56.41	4.88
42.0 - 47.0	4430	.3606E-05	.3536E-05	-56.49	4.70
47.0 - 52.0	2946	.3738E-05	.6482E-05	-56.48	4.60
52.0 - 57.0	1687	.3751E-05	.5372E-05	-56.45	4.53
57.0 - 62.0	1080	.3647E-05	.3590E-05	-56.38	4.53
62.0 - 67.0	718	.3483E-05	.3601E-05	-56.47	4.25
67.0 - 72.0	396	.3841E-05	.3739E-05	-56.04	4.36
72.0 - 77.0	289	.4015E-05	.3760E-05	-55.73	4.22
77.0 - 82.0	130	.5121E-05	.4613E-05	-54.75	4.40
82.0 - 87.0	35	.2782E-05	.2499E-05	-57.16	3.60
87.0 - 92.0	28	.2038E-05	.1617E-05	-58.44	4.09
92.0 - 97.0	0	.0000E-00	.0000E-00	-00.00	0.00
Total	80748	.4316E-05	.5428E-05	-56.54	5.48

[a] Target strength determined from dual-beam data collected *in situ*. File: 6aptab94.w51

Appendix A.7. Average backscattering cross section (sigma) and target strength data by depth strata for Skilak Lake, Alaska, 25 April 1994.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	91	.2145e-04	.4911E-04	-53.26	8.13
7.0 - 12.0	502	.1290E-04	.2616E-04	-54.41	7.36
12.0 - 17.0	2575	.7448E-05	.1779E-04	-55.94	6.41
17.0 - 22.0	4177	.4823E-05	.1448E-04	-57.04	5.80
22.0 - 27.0	6136	.2475E-05	.3310E-05	-59.20	5.40
27.0 - 32.0	5995	.2165E-05	.3267E-05	-59.69	5.36
32.0 - 37.0	2195	.2128E-05	.3102E-05	-60.15	5.56
37.0 - 42.0	1151	.2804E-05	.4221E-05	-59.19	5.83
42.0 - 47.0	865	.2754E-05	.4043E-05	-58.87	5.65
47.0 - 52.0	665	.3142E-05	.4100E-05	-58.44	5.82
52.0 - 57.0	853	.4075E-05	.4344E-05	-56.60	5.37
57.0 - 62.0	418	.3615E-05	.3935E-05	-56.92	4.98
62.0 - 67.0	287	.3795E-05	.4148E-05	-56.46	4.71
67.0 - 72.0	117	.4817E-05	.5866E-05	-56.03	5.33
72.0 - 77.0	59	.3571E-05	.2516E-05	-55.68	3.69
77.0 - 82.0	21	.2364E-05	.1804E-05	-57.78	4.03
82.0 - 87.0	6	.8569E-06	.5824E-06	-61.82	3.89
87.0 - 92.0	2	.6369E-06	.4249E-06	-62.51	3.15
92.0 - 97.0	2	.6685E-06	.5678E-06	-62.72	4.26
Total	26117	.3645E-05	.1002E-04	-58.41	5.85

[a] Target strength determined from dual-beam data collected *in situ*. File 7aptab94.w51

Appendix A.8. Average backscattering cross section (sigma) and target strength data by depth strata for Skilak Lake, Alaska, 29 April 1994.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	876	.1075E-04	.1487E-04	-53.85	6.76
7.0 - 12.0	4799	.8236E-05	.1757E-04	-54.83	6.22
12.0 - 17.0	9188	.5776E-05	.8783E-05	-55.81	5.93
17.0 - 22.0	9488	.4493E-05	.8667E-05	-56.78	5.82
22.0 - 27.0	7011	.3677E-05	.6489E-05	-57.56	5.63
27.0 - 32.0	3142	.2787E-05	.3299E-05	-58.61	5.54
32.0 - 37.0	945	.2495E-05	.2819E-05	-58.94	5.41
37.0 - 42.0	319	.1986E-05	.2521E-05	-60.18	5.44
42.0 - 47.0	175	.2132E-05	.2686E-05	-59.80	5.38
47.0 - 52.0	151	.2053E-05	.2315E-05	-59.41	4.89
52.0 - 57.0	66	.2238E-05	.2188E-05	-58.74	4.90
57.0 - 62.0	48	.2801E-05	.2164E-05	-57.28	4.51
62.0 - 67.0	36	.7845E-05	.7229E-05	-53.89	5.83
67.0 - 72.0	34	.2268E-05	.1511E-05	-57.71	3.72
72.0 - 77.0	23	.2692E-05	.2291E-05	-57.88	5.23
77.0 - 82.0	2	.5672E-05	.5891E-05	-54.15	5.76
82.0 - 87.0	0	.0000E-00	.0000E-00	-00.00	0.00
87.0 - 92.0	7	.2156E-05	.1249E-05	-57.49	3.14
92.0 - 97.0	0	.0000E-00	.0000E-00	-00.00	0.00
Total	36310	.5056E-05	.9911E-05	-56.63	5.98

[a] Target strength determined from dual-beam data collected *in situ*. File 8aptab94.w51

Appendix A.9. Average backscattering cross section (sigma) and target strength data by depth strata for Skilak Lake, Alaska, 27 September 1994.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	423	.1543E-04	.4321E-04	-53.12	6.98
7.0 - 12.0	3096	.1216E-04	.1979E-04	-53.16	6.61
12.0 - 17.0	8346	.9831E-05	.1262E-04	-53.53	6.21
17.0 - 22.0	13057	.8209E-05	.1005E-04	-54.02	5.98
22.0 - 27.0	13804	.6953E-05	.1122E-04	-54.47	5.62
27.0 - 32.0	10873	.6303E-05	.6162E-05	-54.50	5.31
32.0 - 37.0	5256	.5938E-05	.5980E-05	-54.48	5.01
37.0 - 42.0	1701	.5764E-05	.1885E-04	-54.83	4.91
42.0 - 47.0	445	.5643E-05	.6458E-05	-54.78	4.94
47.0 - 52.0	397	.8674E-05	.3072E-05	-53.99	5.39
52.0 - 57.0	449	.8343E-05	.1067E-04	-53.72	5.60
57.0 - 62.0	481	.8123E-05	.7896E-05	-53.17	5.11
62.0 - 67.0	317	.6886E-05	.5823E-05	-53.31	4.31
67.0 - 72.0	190	.6776E-05	.5952E-05	-53.25	4.11
72.0 - 77.0	160	.7359E-05	.5085E-05	-52.79	4.35
77.0 - 82.0	83	.7352E-05	.5286E-05	-53.39	5.69
82.0 - 87.0	30	.5997E-05	.6670E-05	-56.42	7.41
87.0 - 92.0	29	.7060E-05	.4295E-05	-52.61	3.98
92.0 - 97.0	12	.2928E-05	.4147E-05	-60.55	7.70
Total	59149	.7747E-05	.1183E-04	-54.14	5.73

[a] Target strength determined from dual-beam data collected *in situ*. File 9aptab94.w51

Appendix A.10. Average backscattering cross section (sigma) and target strength data by depth strata for Kenai Lake, Alaska, 7 October 1994.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	40	.9215E-05	.2490E-04	-58.70	8.32
7.0 - 12.0	312	.1235E-04	.1707E-04	-53.71	7.39
12.0 - 17.0	1570	.1033E-04	.1418E-04	-53.97	6.82
17.0 - 22.0	4462	.8254E-05	.9306E-05	-54.25	6.27
22.0 - 27.0	6734	.7578E-05	.8410E-05	-54.15	5.78
27.0 - 32.0	6729	.6439E-05	.6675E-05	-54.66	5.54
32.0 - 37.0	3818	.5857E-05	.6062E-05	-54.75	5.24
37.0 - 42.0	998	.5339E-05	.5200E-05	-55.14	5.18
42.0 - 47.0	140	.5274E-05	.4891E-05	-55.04	5.01
47.0 - 52.0	65	.4433E-05	.5466E-05	-55.82	4.69
52.0 - 57.0	24	.3200E-05	.3155E-05	-56.75	4.07
57.0 - 62.0	4	.2422E-05	.1173E-05	-56.76	2.96
62.0 - 67.0	1	.5676E-05	.0000E-00	-52.46	0.00
67.0 - 72.0	3	.1723E-05	.1880E-05	-59.40	4.70
72.0 - 77.0	3	.5876E-06	.5324E-06	-63.42	3.66
77.0 - 82.0	0	.0000E-00	.0000E-00	-00.00	0.00
82.0 - 87.0	0	.0000E-00	.0000E-00	-00.00	0.00
87.0 - 92.0	2	.8069E-06	.7969E-06	-62.38	5.31
92.0 - 97.0	2	.1918E-06	.1481E-06	-67.94	3.76
Total	24907	.7245E-05	.8527E-05	-54.44	5.81

[a] Target strength determined from dual-beam data collected *in situ*. File 10apt94.w51